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WITH A SEPARATELY-PAGED APPENDIX OF

MINERALOGICAL ABSTRACTS

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PROSPECTUSES ON APPLICATION

THE MINERALOGICAL MAGAZINE

AND

JOURNAL OF

THE MINERALOGICAL SOCIETY.

No. 115. December, 1926. Vol. XXI.

MINERALOGICAL SOCIETY

(Instituted February 3, 1876.)

JUBILEE CELEBRATION

(September, 1926.)

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A COMMITTEE consisting of the President, Treasurer, General Secretary, Foreign Secretary, Editor, Prof. A. Hutchinson, Sir Henry A. Miers, Mr. W. Campbell Smith, Dr. G. F. Herbert Smith, and Dr. H. H. Thomas was appointed by the Council of the Society on November 3, 1925, to consider how the Jubilee of the Society should be celebrated. This Committee, to which Dr. A. Brammall and Mr. Arthur Russell were afterwards added, held several meetings. The General Secretary (Dr. G. T. Prior) had charge of the general arrangements, the Treasurer (Mr. F. N. Ashcroft) of the financial arrangements, the housing

of the official guests, and the Dinner, Mr. W. Campbell Smith of the Conversazione, Prof. A. Hutchinson of the Northern Excursion, and Mr. Arthur Russell of the Southern Excursion. The special thanks of the Council and of the Society are due to these gentlemen for their work, which resulted in an unqualified success.

An informal dinner was held in London on February 2, 1926, the last day of the fiftieth year of the Society's existence. Seventeen members and two visitors were present. During this dinner the proposed arrangements for the celebration in September were discussed informally, and a guarantee fund was opened to meet the general expenses and for the entertainment of guests. The thanks of the Society are due to those who contributed so generously to this fund and so enabled the celebrations to be carried out.

A preliminary notice was circulated in January, 1926, and a provisional programme in April. The final programme, issued in September, is reprinted below.

During the celebrations in London the majority of the delegates and guests were entertained by the Society at Bailey's Hotel, Gloucester Road, South Kensington; and others were provided for by the private hospitality of the President and Mr. Ashcroft. The visitors to Cambridge were entertained in Pembroke College by Professor Hutchinson.

Programme.

Head-quarters: Mineral Department, British Museum (Natural History), South Kensington, London, S.W. 7.

General Secretary: Dr. G. T. Prior, F.R.S.

September 12–18.—Excursion to Devon and Cornwall: Director, Mr. Arthur Russell [p. 124].

Tuesday, September 21.—11 a.m. Informal meeting in the Mineral Gallery, British Museum (Natural History), South Kensington, S.W. 7.

12 noon. Imperial College of Science (Geological Department), Prince Consort Road, South Kensington, S.W. 7. [p. 104].

2.30 p.m. Royal Institution, 21 Albemarle Street, W. 1. Sir William Bragg's laboratories [p. 105].

3.30 p.m. Museum of Practical Geology, Jermyn Street, S.W. 1 [p. 105].

8.30 p.m. Conversazione (by kind permission) in the Rooms of the Geological Society of London, Burlington House, Piccadilly, W. 1.

Reception by the President of the Mineralogical Society, Prof. W. W. Watts, F.R.S., 8.30-9.0 p.m. President's Address at 9.15 p.m. [p. 106]. Exhibition of apparatus and specimens [p. 101].

Wednesday, September 22.—11 a.m. to 1 p.m. University College, Gower Street, W.C. 1. The Johnston-Lavis collection of Vesuvian minerals and rocks [p. 105].

Exhibition of apparatus and specimens in the Rooms of the Geological Society of London, Burlington House, W. 1.

2 p.m. Imperial Institute, South Kensington, S.W. 7. Mineral Collections from British Dominions and Colonies. Reception by Sir Richard Redmayne, K.C.B. [p. 105].

3 p.m. British Museum (Natural History), South Kensington, S.W. 7. Reception on the Grand Staircase by the Trustees and the Keepers of Geology and Mineralogy. Visit to the Mineral Gallery. Photograph taken of the party in the Museum Forecourt at 4.15 p.m. Tea provided at 4.30 p.m. in the Board Room [p. 106].

7.30 for 7.45. Dinner at the Connaught Rooms, Great Queen Street, W.C. 2 [p. 103].

September 23-30.—Excursion to North of England: Director, Prof. A. Hutchinson, F.R.S. [p. 128].

October 1.—Visit of Northern Excursion Party to Cambridge: University Mineralogical Department and Dr. Tutton's Laboratory [p. 133].

Reception and Conversazione.

The Conversazione was held on the evening of Tuesday, September 21, in the rooms of the Geological Society of London in Burlington House, by kind permission of the Council of that Society, the arrangements being under the direction of Mr. W. Campbell Smith. The company, numbering 130, was received by the President and the General Secretary, and the President afterwards delivered an address in the Meeting Room [p. 106]. Refreshments were provided in the Council Room and the following exhibits of apparatus and specimens were displayed in the Upper Library.

1. *Professor W. L. Bragg, F.R.S., The University, Manchester.*—

The Crystal-structures of some well-known Minerals. The exhibit showed the structures of a number of minerals which have been analysed by means of X-rays. The models were constructed to scale—in most of them one centimetre corresponding to an Ångström unit (10^{-8} cm.) in the actual crystal-structure. Interesting features of some of the minerals were described more fully in the labels which were attached to the models.

2. *The Director of H.M. Geological Survey of Great Britain.*—

Polarizing Microscope with rotating nicols, 'Dick' pattern. Designed in its earlier form by the late Mr. Allan B. Dick [Min. Mag., 1889, 1910].

Stage Goniometer, for use with 'Dick' Petrological Microscope. Designed in its earlier form by Sir Henry A. Miers [1892].

Universal Goniometer. This apparatus, designed by Professor Arthur Hutchinson, can be used: (1) as a goniometer for the measurement of crystal-angles; (2) for the measurement of optic axial angles; (3) as a Kohlrausch total-reflectometer; (4) for the measurement of refractive indices by the prism method [Min. Mag., 1911].

Crystal Grinding Apparatus, for the grinding and polishing of accurately orientated crystal plates or prisms. Designed and described by Dr. H. H. Thomas and Mr. W. Campbell Smith [Min. Mag., 1914].

Tank Refractometer, for determining the refractive indices of liquids. Designed by Dr. H. H. Thomas and Mr. A. F. Hallimond [Min. Mag., 1920].

Magnetic Separator, electrically driven. Designed by Mr. A. F. Hallimond.

3. *Professor H. L. Bowman, Mineralogical Dept., University Museum, Oxford.*—

Early Apparatus for the Examination of Crystals under the Microscope.

Dr. H. B. Leeson's Double Refracting Goniometer and Adjusting Stage.

The Goniometer is intended for the measurement under the microscope of the plane angles of a crystal face. It consists of a double-image prism of calcite or quartz mounted in a rotating eyepiece and provided with a graduated circle.

The Adjusting Stage fixed to the stage of a microscope provides for the rotation of the crystal in three planes at right angles. It was intended primarily for supporting a crystal so that one of its faces could be set at right angles to the axis of the microscope, for measurement with the double refracting goniometer. It could also be used for determining the inclination of an optic axis to a crystal face. This apparatus may thus be regarded as an early form of the universal stage. It was designed and described by Dr. H. B. Leeson in 1848 [Mem. Proc. Chem. Soc., 1848].

Small Adjusting Stage for inclining sections at small angles to the stage of a microscope. Probably made for Professor N. Story-Maskelyne. This apparatus, which is arranged to take ordinary microscope slides, is capable of inclination about two axes at right angles to each other.

Crystallonome, designed by Dr. H. B. Leeson. An instrument for studying the laws and properties of crystalline form, allowing for variation in position and length of wires representing crystal axes. It could be used also with the compass points for the solution of various problems of spherical trigonometry.

4. *Professor Arthur Hutchinson, F.R.S., Mineralogical Laboratory, Cambridge.*—

Total Reflectometer, designed by William Hyde Wollaston about 1802.

Two-circle Goniometer, used by Professor W. H. Miller in 1874. A small Wollaston goniometer was fixed in an upright position on a graduated horizontal circle of a large goniometer so that the crystal lay at the intersection of their axes. This apparatus was devised to measure the facets on a small bead of platinum.

A Protractor for use in constructing stereographic and gnomonic projections of the sphere. Designed and described by Professor Hutchinson in 1908. In a later paper it was explained how the protractor could be used for the interpretation of Laue crystal photographs [Min. Mag., 1908, 1926].

A Stereographic Net 12 inches in diameter and graduated to degrees.

Alignment Charts for use in crystal-optics; intended to facilitate the solution of problems involving such equations as:

$$n = \frac{\sin i}{\sin r}; \quad n = \sin\frac{A+D}{2} \Big/ \sin\frac{A}{2}; \quad n' = n\sin\theta \text{ [Min. Mag., 1925].}$$

Chart for the graphical correction of specific gravities [Min. Mag., 1924].

5. *Dr. G. F. Herbert Smith.*—

The 'Herbert Smith' Refractometer, particularly for the discrimination of faceted gem stones. Designed by Dr. Herbert Smith in 1907 [Min. Mag., 1905, 1907].

A Students' Goniometer, described and designed by Dr. Herbert Smith in 1919 [Min. Mag., 1919].

Protractors: (*a*) for stereograms, in particular for the drawing of circular arcs; (*b*) for graphs in general and gnomonic projections in particular [Min. Mag., 1903, 1913].

6. *Mr. Bristow J. Tully.*—

The 'Tully' Refractometer, for determining the refractive indices of gem stones.

Verneuil's Inverted Blowpipe, for the manufacture of crystallized corundum, together with a series of 'boules' and cut gems produced by artificial means.

A Series of Precious Stones illustrating variations of colour found in each species.

7. *Mr. J. C. Taylor.*—

A Selection of Crystals of Quartz, Calcite, &c., illustrating various phenomena of crystal-growth.

8. *Mr. F. N. Ashcroft.*—

A Selection of Minerals from Swiss localities.

9. *Professor A. Liversidge, LL.D., F.R.S.*—

Sections of Gold Nuggets to show their crystallized structure.

10. *Colonel Sir Henry G. Lyons, F.R.S.*, Director of the Science Museum, London.—

Minute-book of the British Mineralogical Society (1799–1806) [p. 109].

Dinner.

The Dinner was held in The Connaught Rooms, Great Queen Street, London, at 7.45 p.m. on Wednesday, September 22. Seventy Members, Delegates, and Guests were present. The Menu card showed a portrait,

here reproduced [p. 112], of Henry Clifton Sorby, the first President of the Society. The toasts were:

The King.

Heads of Foreign States.

The Mineralogical Society. Proposed by Dr. Harry von Eckermann (Sweden) and Prof. Paul Niggli (Switzerland), and responded to by the President.

Academies and Scientific Societies. Proposed by Sir Henry A. Miers, F.R.S., and responded to by Prof. F. W. Clarke (U.S.A.) and Prof. J. L. H. Borgström (Finland).

The Delegates and Guests. Proposed by Sir Thomas H. Holland, K.C.S.I., K.C.I.E., F.R.S., and responded to by Prof. F. Rinne (Germany) and Dr. H. Ungemach (France).

Finally, Sir John S. Flett, K.B.E., F.R.S., proposed a vote of thanks to the President, who in his reply referred to the work of the Entertainment Committee. The interesting and inspiring speeches were in all cases delivered in English.

Addresses from the Royal Geological Society of Cornwall and the Polish Geological Society were read by the delegates (Mr. E. H. Davison and Prof. S. Kreutz) of those Societies, and the President mentioned various letters and telegrams of congratulation [p. 134].

Greetings were dispatched by telegram to the older Honorary Members —Prof. G. Tschermak, Prof. P. Groth, Prof. E. S. Dana, and Prof. Victor Goldschmidt—and to some of the early Ordinary Members of the Society who were unable to be present—Mr. Benedict Kitto, Prof. A. Liversidge, Dr. Richard Pearce, and Mr. C. J. Woodward.

Visits to Museums and Institutions.

Imperial College of Science and Technology (*Royal School of Mines*).—The party was received by the President of the Society, who is Professor of Geology in the College. An instructive demonstration was first given by Prof. H. C. H. Carpenter, F.R.S., in the lecture theatre of the Metallurgical Department on large single crystals of aluminium, copper, silver, and gold. The party was then conducted through the Geological Department by Prof. W. W. Watts, Prof. C. G. Cullis, Dr. J. W. Evans, Dr. A. Brammall, and Mr. H. B. Milner. Several interesting exhibits illustrating teaching and research had been set out for the occasion. A number of the visitors were afterwards entertained to luncheon by Prof. Watts in the College Union.

The Royal Institution of Great Britain.—A fine series of models and apparatus illustrating recent X-ray work on crystals was displayed in the Library. These were explained by Sir William Bragg, K.B.E., F.R.S., and members of his staff—Dr. G. Shearer, Dr. A. Müller, Mr. W. T. Astbury, Dr. W. A. Caspari, Dr. I. E. Knaggs, Miss K. Yardley, and others. Small groups were conducted through the rooms and workshops of the Davy-Faraday Laboratory. Items of historical interest connected with Count Rumford, Davy, Faraday, Tyndall, and Dewar were pointed out.

Museum of Practical Geology.—The party was received by Sir John S. Flett, K.B.E., F.R.S., Director of the Geological Survey of Great Britain and of the Museum. Groups were shown round by members of the staff—Mr. J. Allen Howe, Dr. H. H. Thomas, Dr. W. F. P. McLintock, and Mr. A. F. Hallimond. A series of special exhibits had been arranged for the occasion by Mr. Hallimond. Tea was afterwards kindly provided by Sir John Flett in the Library.

University College.—The visitors were received by Sir Gregory Foster, Provost of the College, and the Johnston-Lavis collection of Vesuvian minerals and rocks was demonstrated by Mr. K. W. Earle. The Collection was formed during many years by the late Dr. Henry James Johnston-Lavis (1856–1914), formerly Professor of Vulcanology in the University of Naples. It was bequeathed by him to the University of London, for the purpose of forming a geophysical section of the geological museum of University College. The collection is temporarily housed at 134 Gower Street, close to University College, where it was formally opened in 1925.

Imperial Institute.—The party was received in the Conference Room by the Director, Lieutenant-General Sir William Furse, K.C.B., and by Sir Richard Redmayne, K.C.B., Chairman of the Advisory Council on Mineral Resources. The aims and scope of the newly reorganized Institute, especially of the Mineral Resources Department, were explained. Various minerals of economic importance were displayed, and the mineral publications of the Institute were freely given to members of the party. The new arrangement of the Exhibition Galleries was explained in the New Zealand Court, and Mr. T. Crook took a portion of the party a rapid tour through some of the other galleries.

British Museum (*Natural History*).—On the morning of September 21 in the Mineral Gallery there was an informal gathering at which the Delegates, Guests, and Members became known to one another. Names were signed in the Society's Signature Book. General information, circulars, and tickets were given out.

On September 22 a reception was held on the Grand Staircase by the Trustees (Lord Rothschild, F.R.S., Lord Ullswater, G.C.B., Sir David Prain, F.R.S., and Sir Henry A. Miers, F.R.S.), the Keepers of Geology and Mineralogy (Dr. F. A. Bather, F.R.S., and Dr. G. T. Prior, F.R.S.), and the Assistant Secretary (Dr. G. F. Herbert Smith). The visitors were then shown round the Mineral Department by members of the staff (Dr. Prior, Dr. L. J. Spencer, F.R.S., Mr. W. Campbell Smith, and Mr. E. D. Mountain), and some few were taken to the Geology Department by Dr. Bather. A photograph [plate II] of the party, numbering 60, was taken in the forecourt of the Museum, and tea was afterwards provided by the Museum in the Board Room.

Address of the President.

Fifty Years' Work of the Mineralogical Society.

William Whitehead Watts, Sc.D., LL.D., F.R.S., F.G.S.
Professor of Geology at the Imperial College of Science and Technology.

My first duty, and it is indeed a pleasant one, is to offer, on behalf of the Council and the Membership of the Mineralogical Society, the warmest and most cordial of welcomes to the Delegates of Foreign Mineralogical Societies, and to all our Guests, Foreign and British, not forgetting those from Overseas, and to thank them in no measured terms for the distinguished honour they have conferred upon us by sharing in the celebration of the first fifty years of our Society.

Coming from all parts of the world, from Finland to South Africa, 'from China to Peru', it is a great delight to welcome those distinguished workers whose names we have for long held in honour. But now that we have grasped their hands and talked with them on all kinds of subjects, we know them as human beings, more human perhaps than we could have guessed from their papers.

Others there are who from age or illness or mischance have not been able to be present in person, but have sent their cordial greetings either in formal addresses or in personal and charming letters.

We wish to preserve a signed record of all those who have honoured us with their presence, and we ask those who attend the jubilee to sign their names in what will be kept for posterity as our golden book.

The Mineralogical Society of Great Britain and Ireland is one of the few scientific societies that does not make a practice of asking its

Presidents to deliver an annual address. As a matter of fact only five such addresses have been delivered—one by the first President, Henry Clifton Sorby, in 1877, one of purely formal character by W. H. Hudleston in 1883, two by Professor T. G. Bonney (1884 and 1885), and one, the last, by Sir Lazarus Fletcher in 1888. They have varied in character from purely scientific papers to accounts of the work and position of the Society, but they have generally tended towards a hortatory or disciplinary tone in relation to the scope of the Society's work or the nature of the papers submitted to it. Two Presidents, Dr. Sorby and Mr. W. Barlow, in 1879 and 1915, followed up the formal business of annual meetings with papers, but these were not intended to be of the nature of addresses, and the former of them was, with other papers, taken as read. Dr. Sorby and Professor W. J. Lewis read papers after the business of the annual meetings at which they resigned.

Sir Lazarus Fletcher, surely one of the most genial and kindly of men, and withal one of the most humorous, discussed the question of annual addresses in 1888, and a few of his words are well worth quotation. After pointing out that a communication on a specific subject is better presented as a paper, when the investigation is completed and full discussion is possible, than as an address on a set occasion, he continues:

'The simplest permanent arrangement of this kind is that which makes it deal with the progress of the society or of the science during the interval which has elapsed since the delivery of the next preceding address.'

But having said this, he makes it clear that in the case of the Mineralogical Society an address of the kind advocated could hardly become an annual event, for:

'To set aside annually one-third or even one-fourth of the time of the Society for consideration of the views of the President or of the progress and past work of the Society would seem to be wanting in regard to proportion. A few minutes spent by the members in turning over the pages of the Magazine will give a better idea of the work of the Society, and be at the same time more exhilarating, than any summary a President can make.'

The conclusion is admirable, but it depends a little too much upon an inverted hyperbole. I do not think that 'turning over the pages' even 'for a few minutes' of those parts of the Magazine, for instance, which tell about the Optical Indicatrix, or Mr. Barlow's paper 'On Homogeneous Structures and the Symmetrical Partitioning of them, with application to Crystals', would give even a member of the Society a very complete

conception of the Society's work or the expression of it. Indeed, in almost the next sentence he says :

'It may be cast in our teeth that the volume is small, but we can proudly and truly retort that few volumes of the same size furnish so vast an amount of heavy reading. The density, indeed, is prodigious—not that of lead, but of gold, refined gold. The volume is intended for transmission to all posterity, and not as a mere addition to the ephemeral literature and scientific gossip of a too prolific century. The present generation, by its careful use of the volume, will doubtless help it to reach its destination.'

It is noteworthy that Fletcher's successor in the Chair, Dr. R. H. Scott, famous as a Meteorologist no less than as a Mineralogist, and for seven years Secretary, gave no address during his three years of office, although he is stated to have been responsible for urging Professor Bonney to write the address with which he closed each year of his presidency ; it may be fairly suspected that he had some influence with Fletcher as well.

Since the date of the last address delivered to the Society, that of Fletcher from which I have been quoting, thirty-eight years have slipped away and the Society has attained its fiftieth birthday. It may be, therefore, that I shall not be consuming an undue proportion of the Society's time if I venture to give an account, however brief and inadequate, of the leading features of the Society's progress and work during the first fifty years of its life.

The British Mineralogical Society (1799–1806).

At the outset, it has to be stated that our Society was not the first of its kind in this country. It had a predecessor over a century and a quarter ago. There are two references to it, as Dr. Spencer has kindly pointed out to me, in the Mineralogical Magazine ; but the best account is to be found in the charming history which Mr. H. B. Woodward prepared for the Centenary of the Geological Society, from which I extract the following (p. 7) :

'Among the books formerly in the Library of the Museum of Practical Geology, and since transferred to the Science Library of the Victoria and Albert Museum, was the MS. Minute Book of the Proceedings of the British Mineralogical Society. From this we learn that at a meeting held in the Askesian Society's room at Plough Court on April 2, 1799—present : William Allen, W. H. Pepys, Alexander Tilloch, Richard Knight, and Wilson Lowry—it was " Resolved that those present do form themselves into a society under the denomination of the British Mineralogical Society ". Laws and regulations to the extent of twenty-seven were framed at a subsequent meeting held on April 30. The number of members was not to exceed twenty. For the present none were to be admitted members

"but such as were able and willing to undertake a chemical analysis of a mineral substance".'

The Minute-book referred to is still preserved in the Science Library, and, by the kind permission of the Director of the Science Museum and Librarian, Sir Henry G. Lyons, is exhibited on this occasion.

Allen and Pepys were both members of the Society of Friends. The former was founder of the firm of Allen and Hanbury, the latter a descendant of Sir Richard Pepys, Lord Chief Justice of Ireland. Arthur Aikin (spelt in the Minute-book Aiken) appears to have been President and Pepys Secretary from 1801 till December 1806. The proceedings were reported, and some of the papers read were published, in the Philosophical Magazine (1798–1813), and among its other work the Society circularized 'Farmers and other Persons engaged in Experiments in Agriculture' offering to

'examine, free of expense, all specimens of earths or soils, with a view to determining the nature and proportion of their different contents, with as much accuracy as shall seem requisite'.

Indeed, it is evident that the main function of the members was to analyse mineral substances and to communicate their findings to each other for discussion. Their interests lay with general science and hardly with mineralogy as it would now be defined. Accordingly we find that the Society amalgamated with the Askesian Society (in whose room it had continued to meet) in 1806, and from the strength of the combined societies was drawn the group of thirteen remarkable men who on November 13, 1807, formed the 'little talking Geological Dining Club' which grew so rapidly into the Geological Society of London.

In addition to those mentioned already, the founders of the Geological Society who were Mineralogists included Davy, de Bournon, and Parker, with R. and W. Phillips. These men, and their successors, contributed the results of their mineralogical and petrological work to the publications of the Geological Society for many years; but as those publications became more and more taken up with other branches of geology, palaeontological, stratigraphical, physical, and so forth, it eventually became advisable to found a new society more exclusively devoted to mineralogy.

Foundation of the Mineralogical Society of Great Britain and Ireland.

Much preliminary work was done, especially by J. H. Collins and his associates, and on February 3, 1876, a meeting was held at the Scientific Club, 7 Savile Row, London, with Henry Clifton Sorby in the Chair, at which it was resolved to found a society to advance the study of Minera-

logy and Petrology, to be called 'The Mineralogical Society of Great Britain and Ireland'.

Bye-laws and Meetings.

A code of Rules was drawn up and the Society was to consist of Ordinary Members, Associates, and (Overseas and Foreign) Corresponding Members. Officers and Council were elected, many of whom remained closely associated with the Society for many years, four of them serving as Presidents. H. C. Sorby was elected President and J. H. Collins Secretary, his duties including the editing of the Magazine.

Four other meetings were held in 1876, and the Society gradually expanded, until, at the second annual meeting held on August 15, 1877, the Report of the Council was able to announce that the printed list contained the names of 13 Life Members, 112 Annual Ordinary Members, 12 Associates, and 4 Corresponding Members, a total of 141, a figure which approximately represents the fluctuating strength of the Society for many years. At the present time the total is 47 Life Members, 130 Annual Members, and 12 Honorary Members, in all 189. No new Associates seem to have been elected after 1891, and by 1894 the class had died out.

Slight modifications were made from time to time, but there was only one systematic revision of the bye-laws. New ones were made and adopted at the 25th annual meeting in November 1900. Further alterations were made in 1902 and 1916, but the slightness of the changes on each occasion is a tribute to the vision and imagination of the earliest draftsman, who can hardly have been other than the first Secretary, Collins. To this it may be added that it has been unnecessary to introduce any important modification in the procedure at meetings or to make any drastic change in the form and plan of the Magazine, which have been found sufficiently elastic to admit of the additions and improvements rendered necessary by the lapse of time and the advance of science.

While, during the first twelve years, a certain number of meetings were held in London, the Society at that time was peripatetic in its habits. The meetings held outside London were sometimes merely of local members, but in the majority of cases they were full General, and even Council, Meetings. Indeed, the first five Annual Meetings were so held. Five of the meetings were called Local and were held at Redruth, Camborne, Liverpool, Dundee, and Skye, the last being also a Field

Meeting. The second, third, fourth, fifth, and sixth Annual General Meetings were held at Plymouth, Dublin, Sheffield, Swansea, and York, severally, and other General Meetings were held in Glasgow (2), Edinburgh (3), Dundee, and St. Andrews. In 1881, at the Annual Meeting in York, it was resolved that 'all expenses incurred at Local Meetings are to be defrayed by the Members who take part in them'. Possibly, as Hudleston remarks in his address, owing to the natural gravitation towards the capital, or it may be as a result of this resolution, we find that external meetings became much fewer. Only four were held after 1881, all in Scotland, but it is remarked that they were highly successful, no less than thirteen papers being read at one of the Edinburgh meetings. The last of all, at which nine papers were read, was also at Edinburgh on June 28, 1888. Since the Field Meeting at Talisker Bay in Skye in 1880 the Society has never held any formal excursions till this year.

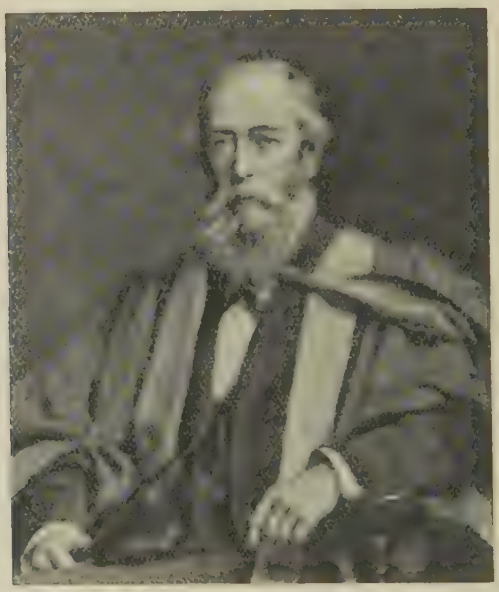
The Officers.

The Society was singularly fortunate in securing as its first President one of the most gifted and eminent scientific men of his day, Henry Clifton Sorby, to whom we owe the application of the microscope to the study of metals, minerals, and rocks. He was not only an ingenious designer of apparatus and methods, but possessed a great knowledge of the principles of physics and chemistry, and the ability to apply even the most recondite of them to his special problems. Moreover, though charmed by the ingenuity and beauty of his own methods, he always regarded them as means to an end, and took little further interest in them unless they led to advance in some problem of physical geology, such as the deposition of sediment and the elucidation of ancient physiographies, or helped to explain the characters or conditions of origin of rocks or minerals. He loved to work out new methods, make proof of their value for research, and, then, pass them on to others to whom he imparted some of his own energy and enthusiasm, while he himself turned to a new problem. It was in this way that he started Zirkel and through him the German school of petrology, and Judd and the English school. He has well earned the title of the 'Father of Petrology' bestowed on him recently at Sheffield University.

After three years in office Sorby retired and was succeeded by one who was more strictly a Mineralogist, Professor M. Forster Heddle. Since then there have been fourteen Presidents, their normal tenure being three years. Three, however, have been only able to serve two years each,

while one other served for five and Professor Story-Maskelyne for seven years.

Secretaries have of course been fewer than Presidents and there have been but four in the history of the Society. J. H. Collins acted from the beginning till 1881, R. H. Scott till he became President in 1888, and was replaced by the then retiring President L. (afterward Sir Lazarus)



Henry Clifton Sorby (1826–1908).
First President of the Society.

Fletcher, who held the office for twenty-one years till 1909, when he gave place to Dr. G. T. Prior, the present Secretary, who has served in this capacity for seventeen years.

In the early years finance seems to have depended at least as much upon the Secretary as upon the Treasurer. We learn that in these years strict economy was essential, and the Council frequently complained that it was unable to publish all that it wished to do. Financial matters were taken in hand very seriously by Scott, and improvement is noted year by year under his skilled and generous guidance until, before he relinquished the Secretaryship, he had given the Society freedom from anxiety on this score. Even now, however, with the Society's small

invested capital, it would be impossible to carry on our present programme of publication without special help from a source that will be indicated later, supplemented by a great amount of voluntary labour on the part of the Editor and his band of abstractors.

The Mineralogical Magazine.

At first the Secretary was charged with the task of editing the Magazine, and J. H. Collins acted as Editor till 1881. On his resignation to take up an important appointment at Rio Tinto an Editorial Committee of five, including President and Secretary, was appointed. Apparently the chief burden still fell upon the Secretary, and indeed Scott's services in editing the Magazine are once referred to with gratitude in a Council Report and coupled with an acknowledgement of his success in stabilizing the Society's financial position. Fletcher served in the same capacity for three years and then, though remaining Secretary, he passed on the editing to Sir Henry Miers, who acted for ten years till 1900. Since that date the Magazine has been directed by the firm and competent hand of Dr. L. J. Spencer, who has thus been responsible for half the life of that publication, and has devoted a vast amount of work to it and to the kindred tasks that followed in its train. The name of the Editor was ordered to be printed on the wrapper of the Magazine in 1891.

As has already been said, the Magazine has varied little in form and plan since its initiation, the only revolutionary change coming in 1920 with volume 19. Reviews and Notices occur in every volume but one (vol. 6) and are now continued as part of the 'Abstracts'. Discussions at meetings were not reported after the first volume, and correspondence ceased with vol. 4. Biographical notices and an index to previously published obituaries occur in vols. 19 and 20. In 1883 Sir Henry Miers began a series of 'Lists of Mineralogical Papers' which were published in the Magazine for six years (1883 to 1888), the last one being joint work with Dr. Prior. Their place was to some extent taken by the 'Lists of New Mineral Names' which Dr. Spencer has drawn up for each completed volume from 11 to 20, ten volumes in all. Dr. Spencer has also published at intervals useful and justified criticisms of certain attempts, not always on the soundest or most instructed lines, to regulate mineral nomenclature.

It is evident, from these lists and other features, that from the beginning the Society has been keenly alive to the importance of aiding its members to keep in touch with workers in other countries and in

kindred sciences, and that it could thus be as truly an instrument of research as in the publication of papers. This is further emphasized by the publication of abstracts of papers and other works.

Mineralogical Abstracts.

Abstracts are given in every volume from vol. 6 (1884) up to vol. 14 (1907), in which, however, there are not many. They are selective and in no way profess to give an exhaustive account of contemporary Mineralogical literature. From 1908 to 1919 strength was gathering for a massed attack on this particular problem. It was then resolved to make a serious attempt at the systematic abstracting and indexing of all Mineralogical and Petrological literature. The scheme was organized by Dr. Spencer, who got together a troop of hard-working abstractors, and the first results appeared in volume 19, the work thus making its start in 1920. Although issued with the Magazine the abstracts were paged separately, the material being classified under a number (33) of headings. This may be regarded as a new and separate publication, and it is certainly a valuable contribution to the science and a great service to the workers in it.

In making the abstracts the important subject of indexing has been kept steadily in view. Two indexes have so far made their appearance. Most wisely, as I think, they are not classified, but have a purely alphabetical arrangement, although a supplementary topographical index is appended, localities being grouped under continents, countries, and districts. The latest issued alphabetical index alone fills nearly a hundred pages, which gives some indication of the amount of work which is being done. The designing and carrying out of the project is a great achievement on the part of the Editor, who underwent a hard apprenticeship for many years in preparing slips on Mineralogy and Petrology for the International Catalogue of Scientific Literature, now extinct.

The Society could not by itself have faced the expense of this new venture, and it is a pleasure to record that the Royal Society has made grants to the extent of £385 for the purpose from the sum entrusted to it by the Government in aid of scientific publications.

To any one studying a series of the volumes it is clear that the indexes have been made not only thoughtfully but with intelligence and imagination. The same may be said of Dr. Spencer's author and subject index to the first ten volumes, with its lengthy and portentous list of 'additional errata'. A second period index is now in hand to the second decade of volumes.

Other activities

It should be mentioned that volumes 2 and 4 were accompanied by coloured mineral maps of Shetland and Sutherland, illustrating Professor Heddle's papers on those areas. An uncommon accompaniment to mineralogical papers will be found in volume 2 (p. 271) in an effusion signed with the well-known initials A. G.

The Society's Library was moved to Cambridge in 1890, and in 1925 it was overhauled by Professor Hutchinson and a Committee. It was decided to dispose of works not specially relating to Mineralogy by gift or sale, and to concentrate on those germane to the Society's work.

Outside its regular work the Society took part during the war in protesting against the proposal to utilize the British Museum for any purposes but those which it could best fulfil, whether in peace or war.

The Society joined the Geological Society in nominating a Committee in 1920 on British Petrological Nomenclature, and published the Committee's Report in volume 19. It also sent representatives to take part in the discussion on 'The physical chemistry of igneous rock formation' in 1924 initiated by the Faraday Society, and contributed its quota towards the publication of the papers and discussions thereat.

A fair idea of the history in matters of membership, finance, meetings, and publication can be obtained from the series of reports presented annually by the Council to the Society. In the first half of the period under review the relative importance of the chief papers printed in the Magazine was estimated, but the practice broke down under its own weight, and was dropped.

The Crystallological Society.

Very soon after the Mineralogical Society had got into its stride a new society was founded (on June 14, 1876) under the name of the 'Crystallometric Association', afterwards changed to the 'Crystallological Society', a name apparently intended to imply that special attention was to be paid by it to the geometrical and other properties of crystals in distinction to the wider scope of the older society. W. H. Miller was the first President, W. J. Lewis Secretary, and N. Story-Maskelyne Treasurer. It published two small parts or volumes of 'Proceedings', one in 1877 and one in 1882, with continuous pagination. The earliest papers printed were read in June, 1876, and those published deal with pure crystallography, pure mineralogy, crystallography of artificially prepared substances, apparatus, and to a small extent with rocks.

Except that at first the Mineralogical Society did little purely crystallographic work, there now seems to have been small reason for the existence of a second society so closely allied to the other. Certainly twenty out of the twenty-two published papers would have found themselves quite at home in the Magazine as it was then. Internal evidence, however, seems to indicate that, while the Mineralogical Society was founded and run by those interested in mines as well as minerals, by geologists, and by unofficial mineralogists, the other was more academic and official in outlook and was supported by the Universities and the great Museums. Only two Officers of the British Museum were among the original members of the Mineralogical Society. One of them, Walter Flight, was also a member of the other society, and T. Davies assisted at times and during a good many years in editing our own Magazine.

Negotiations took place between W. J. Lewis and R. H. Scott in 1883 and were so successful that the President, Hudleston, was able to announce that the 'basis of a treaty had been outlined' and confirmed by the Council. A Special General Meeting of our own Society held on December 11, 1883, elected all the members of the Crystallological Society and dispensed with the entrance fee in their case. At the next Council Meeting (February 12, 1884) the Corresponding Members were similarly taken over. In this way the Mineralogical Society gained such men as Story-Maskelyne and Lewis, Fletcher and Miers, 'a small body—mostly men who are likely to be workers and of high repute', and the amalgamation proved to be, as Hudleston had anticipated, 'highly beneficial to both parties, the resultant being perhaps a society more purely mineralogical than that which now exists'.

The lists of Members from that date onwards mark with a 'C' the names of the gentlemen who thus joined us, but this letter occurs only three times in the 1926 list, and now Sir Henry Miers and Mr. C. J. Woodward are the only members of the Crystallological Society that still remain.

Sir Lazarus Fletcher questioned whether a combination of the titles of the two might not have been useful in widening the scope of the amalgamated societies, but I think that it will now be conceded that it would have been a mistake to destroy the compactness and cogency of the present title, so long as nothing which would be of interest to mineralogists, or would tend to advance the science, is excluded from the publications by narrow-minded formalists. In the past we have had no scruples in publishing papers dealing with the theoretical sides of crystallography as well as of mineralogy, and with artificially prepared

substances; and there seems no reason why our usefulness should be cramped in the future by any arbitrary conventions as to scope and limits.

Published Papers.

The Mineralogical Magazine does not give a complete picture of the progress of mineral science in Britain, owing to the fact that certain papers find publication elsewhere. Many petrological papers go to one or other of the Geological Societies, and papers on artificially prepared substances to the Royal or Chemical Societies. Papers on mathematical and structural crystallography also find themselves in increasing numbers in the Royal Society's publications.

When an attempt is made to classify mineralogical papers on lines broadly following those adopted for 'Mineralogical Abstracts', it is surprising how many of the classes are represented even in the first volume of the Magazine, though in many cases only by short papers.

Petrology.—Naturally, with Sorby in the Chair we begin early to find work on petrology, and especially on the microscopic side of it, as well as on crystal-optics. The first paper of the first number is a 'Note upon a portion of Basalt from Mid-Atlantic', a rock dredged up by a cable ship. The paper is the first of several by Marshall Hall, and there is an appendix to it by Clifton Ward on the microscopic character of the rock. A very ingenious paper by Sorby on fluid and other cavities in the minerals of granite draws the conclusion that the felspar crystallized before, and the quartz after, the critical temperature for water had been reached. In the same volume we have Bonney's first paper on the Cornish luxullianite.

The microscopic petrology of igneous rocks forms the subject of many other papers by Bonney, who devotes special attention to ultrabasic rocks and those bearing tourmaline and glaucophane. Riebeckite is noted by the same author, and by Teall and Cole, and its occurrence described at Ailsa Craig and Mynydd Mawr, with the remarkable and almost romantic conclusions to be drawn as to the distribution of the rocks as boulders, a subject on which, however, the last chapter is still to be written. The same mineral from Abyssinia engages the attention of Prior and, from the Sudan, of Campbell Smith. Arctic and Antarctic rocks come up for description by Holmes and by Prior, and while the former deals with collections from Angola, the latter describes alkali rocks and others from such localities as Fernando Noronha, Abyssinia, and British East Africa. Tilley investigates the density of natural glasses, Brammall and

Harwood present a series of results on the Dartmoor granites, and Richardson studies the frequency-distribution of igneous rocks. Geologists are indebted to Miss Kelly for her discovery and description of conchite.

Sediments, and especially the occurrence of detrital andalusite and anatase, are dealt with by Scrivenor and by Thomas, 'cone-in-cone' is discussed by Cole and by Bonney, and septarian concretions and gypsum by Richardson. Teall's discovery of rutile needles in clay should be mentioned here, and a paper on clays by Collins, and also papers by the same writer and Allan Dick on kaolinite. Metamorphism and its minerals are the subject of papers by Teall and by Barrow and Thomas in the west of England, and McMahon in a paper on cordierite-bearing rocks ushers in the modern development of this subject.

Crystal-Optics.—Sorby at a very early meeting read his paper 'On a simple method for determining the index of refraction of small portions of transparent substances', and followed this up in his first Presidential address in 1877, giving at the end tables of indices of refraction and of 'absolute refracting powers'. But except so far as his methods may have been used in mineral determination, no further communications on this subject were made for many years, not indeed until Fletcher flashed out his epoch-making paper on 'the Optical Indicatrix and the Transmission of Light in Crystals' which revolutionized current conceptions and future teaching as to the method of regarding the optical behaviour of minerals.

Many other papers on crystal-optics followed, among which may be mentioned two by Harker on extinction-angles in cleavage-flakes and H. G. Smith's later paper on the same subject, Evans's papers on the determination of optic axial angles and on skiodromes and isogyres, papers by Kôzu and by Tsuboi on problems of dispersion, by Crook on pleochroism and idiophany, and by Cesàro on a formula for the birefringence of a plate. Sorby's last paper, revised by himself shortly before his death and published afterwards, reverted to the subjects of his earlier papers on which he had at intervals continued to work.

Other physical properties and characters.—References to the use of Sonstadt's solution by Heddle and Church occur early, and there is of course plenty of evidence of mineral separation by density and by magnetic and electrostatic means, including a paper on the last by Crook in volume 15. The Earl of Berkeley described in 1895 an accurate method of determining the densities of solids. In volume 3, J. Milne made some experiments, not very conclusive, on the elasticity of crystals. There are two important papers by Professor J. W. Judd: one 'On the

Development of a Lamellar Structure in Quartz-crystals by Mechanical means', accompanied by beautiful illustrations, and another 'On the Structure-Planes of Corundum'.

Descriptive and Topographic Mineralogy.—As these subjects constitute the main business of the Society it is to be expected that the great majority of papers will belong to this category and deal with the discovery of new minerals and new localities. The chief contributions to the first volume are by J. H. Collins and J. B. Hannay. Their papers and those that follow in the long series relate to crystal measurement, chemical composition, optical and other physical qualities and quantities, and discuss relationships and classification. They thus constitute a vast storehouse of fact with regard to British Mineralogy, rendered easily accessible through the thorough indexing of the volumes. The more important of these mineral papers take a monographic form on either a mineralogical or a topographical basis. Examples of important members of the former class follow:

Vol. 6. H. A. Miers, The Crystallography of Bournonite.
Hj. Sjögren, On the Physical and Geometrical Properties of Graphite.
.. 8. H. A. Miers, Contributions to the Study of Pyrargyrite and Proustite.
,, 10. H. A. Miers, Xanthoconite and Rittingerite, with remarks on the Red Silvers.
,, 11. O. A. Derby, Monazite and Xenotime in European Rocks.
,, 12. L. J. Spencer, Plagionite, Heteromorphite, and Semseyite as Members of a Natural Group of Minerals.
,, 12 et seq. R. H. Solly, Sulpharsenites of Lead from the Binnenthal.
,, 13. L. J. Spencer, Mineralogical notes on Western Australian Tellurides: the non-existence of 'Kalgoorlite' and 'Coolgardite' as mineral species.
,, 14. C. O. Trechmann, Crystallography of Sartorite from Binn.
,, 15. L. J. Spencer, On Hopeite and other zinc phosphates and associated minerals from the Broken Hill mines, North-Western Rhodesia.
,, 18. G. F. H. Smith and R. H. Solly, On Sartorite and the problem of its crystal-form.

Papers on Mineral Topography are more abundant in the earlier volumes, and typical examples are those of Professor M. Forster Heddle. Although his papers begin in the first volume, they reach their climax from the second to the fifth. We are not told when or whether they were read, but, if they were, the members of the Society must have been the auditors of one long and continuous Presidential address. Under the title of 'The Geognosy and Mineralogy of Scotland' they treat not only of the minerals with great thoroughness but of the geology (including the rife geological controversies of the time) and other features of Shetland,

Orkney, Caithness, and Sutherland, occupying at least half of the volumes concerned and illustrated with coloured maps in the text or issued as supplements. In addition to this, there is a series of lengthy 'reviews' of his 'Chapters on the Mineralogy of Scotland' classed mineralogically, and published elsewhere. Side by side with these activities there were papers on new Scottish minerals, minerals new to Britain, ill-determined minerals, and many descriptions of mineral species, including haughtonite. Surely no President ever took so liberal a view of his duties as leader of a society; and long after he ceased to be President the stream of his papers continued to flow till his death in 1897.

Some of the topographical papers are limited to British areas, like those by Foster and by Collins, the last a series on Tin-stones and Tin-capels, or by G. F. H. Smith on Antrim zeolites. Others went farther afield like the earlier papers on Alpine minerals, Milne on Japanese minerals, How on Nova Scotia, Howley on Newfoundland, Bowman on minerals at Haddam Neck, Connecticut, and Spencer on Bolivia.

If it be merit to add to the list of known minerals it is perhaps hardly less meritorious to reduce duplication, and there are a number of papers on the identity of minerals described under different names and regarded as different from one another. Readwin, for instance, started the campaign by giving a six-page list of 'Doubtful Minerals' in volume 1.

Meteorites.—Much space in the Magazine is worthily given to papers on meteorites, generally of considerable length, but of very high value from the accuracy and detail of the work, often effected on very small quantities of material. The earliest, 'Contributions towards a History of British Meteorites', by Townshend Hall, includes falls from the year 1360 down to 1876.

Volume 7 begins the magnificent series of papers by Fletcher with one 'On a Meteoric Iron found in 1884 in the Sub-district of Youndegin, Western Australia, and containing Cliftonite, a cubic form of Graphitic Carbon', from which we learn the wonderful skill which the author was capable of displaying in dealing with the most difficult conditions of research. This series runs from 1887 till 1908 and comprises sixteen papers, but there is one published posthumously in 1921 on 'The meteoric stone seen to fall near Crumlin, Co. Antrim, on September 13, 1902', the chemical part of which was added by G. T. Prior.

In volumes 15 and 16 the tale is taken up by Professor H. L. Bowman and H. E. Clarke, and then follow the important series by Prior, comprising fourteen papers beginning in 1910 with one 'On a meteoric stone from Simondium, Cape Colony', and including two on a proposed

classification of meteorites, for which his own and Fletcher's comprehensive investigations provided a broad basis of fact.

In 1922 W. F. P. McLintock and F. R. Ennos give an account of the structure and composition of the Strathmore meteorite. In the early volumes sometimes important foreign papers were translated or abstracted and placed among the original contributions. This is the case, among others, with a paper by Steenstrup and Lorenzen on the nickel-iron showing Widmannstätten figures in the basalt of north Greenland, once thought to be of meteoritic origin.

Chemical Mineralogy.— Chemical analysis being so largely practised by mineralogists and an essential part of their papers, it is natural that we should occasionally meet in the Magazine with useful guidance on methods specially suitable for mineral analysis. This proves to be the case in Foster's papers in volume 1, Burghardt's in volume 9, McMahon's useful notes and tables on the microchemical analysis of the rock-making minerals in volume 10, and Prior's method of estimating nickeliferous iron. Other chemical papers include Carrington Bolton on the action of organic acids on minerals, Church's chemical study of arsenates and phosphates, and Prior and Spencer on the chemical composition of fahlerz. There is a suggestive paper by Carnelley on the application of the periodic law to mineralogy, one by Prior on the connexion between the molecular volume and chemical composition of some similar minerals, and one by Barlow on 'Crystallographic relations of allied substances traced by means of the law of valency-volumes'. Sorby published an interesting note in volume 3 on variations in shape of artificially formed crystals, and from the Oxford University Laboratory came a series of papers, on the characters and growth of crystallized salts, by numerous authors, among whom may be mentioned Barker, Bowman, Drugman, and Kreutz. Finally may be mentioned the important paper by A. E. H. Tutton and Mary W. Porter on the 'Crystallographic constants and isomorphous relations of the double chromates of the alkalis and magnesium'.

There are a few papers on minerals prepared experimentally or artificially. For example, Sorby exhibited artificial pseudomorphs at the first meeting, but does not seem to have described them. Other papers deal with minerals in slags, crystals of iron grown in pig-iron, artificial pyrolusite, agate-like artificial silica, crystalline gypsum, and with synthetic corundum and spinel.

Growth, &c., of minerals.—The growth, repair, and destruction of minerals has been the subject of many papers. Readwin exhibited and described the growth of mineral substances under conditions of ordinary

temperature and pressure, Miers dealt with British pseudomorphs, Rutley with crystallites, and Spencer with the curvature of crystals. On the other hand, Judd paid attention to solution-planes in crystals and their relation to schillerization, the conversion of felspar into scapolite, and the relations between the gliding and solution-planes of augite.

Allied to this is a subject on which we have too few papers, though they are now increasing, namely the physiology of minerals or the conditions regulating their formation under natural conditions. Under this head may be placed Harker's notes on hornblende as a rock-forming mineral, Samoilov on the organic origin of some minerals occurring in sedimentary rocks, Brammall and Harwood on reconstitution processes in shales, slates, and phyllites, Belaiew on the genesis of Widmanstätten structure, Edmondson Spencer on albite in limestone, and Tilley on some mineral transformations in crystalline schists.

Classification.—Again, there are but few papers on classification. They comprise Collins's classification of minerals in volume 2 Taylor on hydrocarbons, Prior on meteorites already alluded to, and Hallimond's classification of the mica group.

Economic mineralogy.—There are not a great number of papers on gems, but the Maxwell-Stuart topaz, the largest cut precious stone then known, and the Cullinan diamond are described. Inclusions and impurities in diamonds have been described, and Hudleston discussed theories as to the origin of the diamond and its parent rock in South Africa. Ruby or sapphire or both are described from localities in New Zealand, Siam, and North Carolina, and Louis sets out the general modes of occurrence of gold, a problem on which new light has recently been thrown by Brammall and Harwood. There are still fewer papers on ores and other substances of economic importance. H. M. Cadell dealt with the age and origin of the veins of the Upper Harz, and Crook had an important paper on the genetic classification of rocks and ore-deposits. There are also some papers on diatomite.

Apparatus and Methods.—Naturally there are a fair number of papers on apparatus, beginning with blowpipe lamps and portable chemical apparatus. Goniometers of novel or convenient pattern, or suitable for students, are brought to notice by Hannay, Miers, G. F. H. Smith, and Hutchinson. The types become increasingly efficient, the series being at present closed by an X-ray goniometer by Greenwood. Allan Dick described his admirable petrological microscope in 1888, and Grabham made improvements on it in 1910. A microscope with rotating stage was described by Richardson in 1920. With these come rock- and

mineral-slicing apparatus dealt with by Ady, G. F. H. Smith, and Thomas with Campbell Smith.

Refractometers are described by G. F. H. Smith in a first and final form, and by Thomas and Hallimond. The quartz-wedge was improved by Evans, who also pointed out extended uses of the slit in microscopic investigation. Many devices for drawings and projection, and for the simplification of calculation, are described by G. F. H. Smith, Richardson, and especially by Hutchinson.

Projections.—Mineral projections are frequently considered, the gnomonic by Miers, G. F. H. Smith, Hilton, and Evans, and the orthographic by Hilton. An ingenious method of making models by 'plaiting' was devised by Gorham, and models of crystal-structure have become more frequent as this line of study has been further developed.

Crystallography.—Pure and mathematical crystallography comes late in the Magazine, the first important paper being that by Barlow 'On Homogeneous Structures and the Symmetrical Partitioning of them, with application to Crystals'. Later came Lewis on Grassmann's method of axial representation and Hudson on the determination of the position of points and planes after rotation about a known axis. Hilton and Evans both dealt with the thirty-two classes of symmetry, and Cesàro's paper on a numerical property of axes of symmetry is especially interesting in calling for the only contribution made directly to the Magazine by Fedorov. Evans dealt with the laws of twinning, and G. F. H. Smith endeavoured to give a theoretical explanation of the structures required to explain the crystallographic anomalies of certain minerals investigated by him.

X-rays and Crystal-structure.—Finally, there are papers on crystal-structure chiefly as revealed by X-ray or X-ray spectroscopic analysis. In this group comes one paper by Sir William Bragg, and there are others by Miss Knaggs, Miss Yardley, and S. I. Tomkeieff.

Conclusion.

From this recital it may be concluded that the Mineralogical Society has justified its existence. Whether we look to the discoveries made in Britain or abroad, at those made among the plutonic rocks below or the meteorites from the heavens above, we cannot fail to be struck by the thoroughness and exactitude of the observations made, by the deduction from them of principles guiding form, structure, or occurrence, and by the presentation of results to an educated public. At no time has the science been more active or the outlook more promising that at present.

Those who will attend the centenary of the Society are to be envied in the wealth of discovery and correlation which the coming years will bring forth not only within our science itself but in the sister sciences with which its relations grow closer every day.

Southern Excursion.

Report by the Director, Mr. Arthur Russell.

This excursion to Devonshire and Cornwall was under the leadership of Mr. Arthur Russell assisted by Captain G. M. Puckle. The party included Sir Charles Russell, Bart. (Swallowfield Park), Sir John S. Flett (London), Prof. T. L. Walker and Mr. James Walker (Toronto), Prof. J. L. H. Borgström (Helsingfors), Dr. R. L. Parker (Zürich), Dr. J. Drugman (Brussels), Mr. James Broadhead (Darlington), Señor J. Folch y Girona (Barcelona), Señor H. Buschor (Barcelona), Prof. B. Gossner (Munich), Dr. H. Steinmetz (Munich), Mr. W. Maucher (Munich), Mr. H. Heertz (Frankfurt a. M.), Mr. S. I. Tomkeieff (Newcastle-on-Tyne), and Mr. W. Campbell Smith (London). The main party travelled from London on Sunday, September 12, and was met by the director at Okehampton. From there the party was conveyed in four motor-cars, the tour, ending at Penzance, covering 281 miles.

Monday, September 13.—Starting from Okehampton, the following localities on the northern fringe of Dartmoor, at or near the junction of the Culm-measure shales with the granite, were visited. Belstone Consols (or Mid Devon) mine, Belstone (formerly worked for copper and arsenic); here excellent specimens of brown to greenish grossular, axinite, and an opal-like mineral were found on the old waste-heaps. The Ramsley mine, South Tawton (copper, abandoned), yielded grossular, axinite, heulandite on Culm-measure shale, and chabazite from an exposure of altered greenstone on the old dressing-floors. At Ford Farm quarry (a locality for andalusite) the actual contact of the granite and Culm-measures was examined. The extensive Meldon quarry, worked by the Southern Railway Company, showed a wonderful section of the contact-rocks, and excellent specimens of wollastonite and pyrrhotine were collected. The old dumps of the Meldon limestone quarry were carefully searched and yielded wollastonite, crystallized apophyllite, and one specimen of garnet showing the rare cube face. The well-known Meldon aplite quarries, now unfortunately abandoned, were also examined and specimens obtained of green and pink tourmaline, wollastonite, petalite, and a single specimen showing two well-defined colourless crystals of an

undetermined mineral. On this day the party was fortunate in having the attendance of Dr. E. H. Young, of Okehampton, who for many years has been an enthusiastic local geologist and petrologist.

Tuesday, September 14.—Again starting from Okehampton and travelling along the Tavistock road, good views were obtained of Brent Tor, concerning which and the general geological features of the district Sir John Flett gave an interesting account. West Wheal Crebor, Tavistock (copper, abandoned), yielded many specimens of childrenite, a mineral which few members of the party had previously collected. Thence, via Tavistock and Callington, to the Cheesewring quarry, Linkinhorne, good views of many of the principal east Cornish mines being obtained along the road. At Callington mineral specimens formerly the property of Mr. Jehu Richards were purchased by several members of the party. The Cheesewring quarry yielded on this occasion several excellent specimens of the rare bertrandite, associated with orthoclase and fluorite. The night was spent at Liskeard.

Wednesday, September 15.—Proceeding to Lostwithiel, Terrace Hill quarry was visited and the interesting exposure of calc-silicate rocks, traversed by what appears to be a small mineral-vein, was examined. Specimens of grossular, axinite, datolite, galena, and pyromorphite were obtained. At Mulberry mine, Lanivet (abandoned), the remarkable open-cast on a tin stockwork in killas was examined, and the dumps yielded specimens of cassiterite and topaz. Tremore quarry, Withiel, which has latterly been somewhat extensively worked, proved specially interesting. Here a fine example of an elvan dike exposed for its full width shows the effects of marginal cooling, and the contact-altered slate contains axinite and fluorite. A crystal of axinite found here by one of the party is probably the largest known from Cornwall. At Belowda Beacon, Roche, north of the old mine, some comparatively recent trial pits afforded good specimens of topaz, gilbertite, and quartz-tourmaline-rock. Castle-an-Dinas wolfram mine, St. Columb Major (abandoned), yielded wolframite, scorodite, and wavellite, the last a mineral known from only one other locality in Cornwall. On this day Lady Molesworth St. Aubyn, Mr. Henry Dewey, and Mr. E. H. Davison joined the party. The night was spent at Truro.

Thursday, September 16.—From Truro the party proceeded to St. Stephen-in-Brannel, where they were met by Mr. W. Boxhall, of St. Austell, Mr. A. Davies, Manager of the English China Clays, Limited, and Mr. Bun, a representative of the local newspaper press. The Tregargus china-stone quarry, the property of Messrs. Olver & Co.,

was first visited, Mr. Boxhall explaining the varieties, characters, and commercial applications of the stone. The process of grinding was also seen. A comprehensive tour was then made of the china-clay district, this having been made possible by the special facilities afforded by the English China Clays, Limited, which company, in addition to allowing a detailed inspection of two of their most representative pits (Hendra

At the Roche Rock, Cornwall.

[B. Gossner, W. Maucher, J. Broadhead, T. L. Walker, Sir John Flett, S. I. Tomkeieff, J. W. Walker, J. Drugman, J. Folch, Sir Charles Russell, G. M. Puckle, Arthur Russell, W. Boxhall, H. Steinmetz, Mr. Bun, H. Heertz, H. Buschor, driver of the car, R. L. Parker, W. Campbell Smith, E. H. Davison.]

and Dorothy), also kindly provided an excellent lunch at which one of the directors, Mr. R. Large, presided. The members of the party were able to see both the old system of washing out the clay as well as the latest high-pressure monitors, and also the entire process of preparation and drying. To any one unfamiliar with the district, the magnitude of the operations affords an impressive sight, and the foreign guests in particular were much impressed by the importance of the industry. The remainder of the day was occupied at Hensbarrow Beacon, Roche Rock, and the felspar quarries at Tresaize (Glass mine) with a fine example of a pegmatite vein. The night was again spent at Truro.

Friday, September 17.—The morning was spent at Truro visiting the County Museum of the Royal Institution of Cornwall, where the party was met and courteously conducted by Canon H. Holroyd Mills and the curator, Mr. George Penrose. Members were allowed to handle and examine in detail many of the remarkably fine specimens in the Philip Rashleigh collection, notably the magnificent examples of liroconite and clinoclase. In the afternoon the party proceeded to Perranporth, and was joined by Mr. C. H. Trenerry, who most kindly conducted the members to Cligga Head, remarkable for its fine exposures of tin and wolfram veins, old cliff workings, and beautiful examples of greisenization. Many of the members descended the rather awkward cliff, and specimens of cassiterite, wolframite, scorodite, and topaz were collected. The night was spent at Perranporth.

Saturday, September 18.—On this last day the party proceeded to Tresavean mine, Gwennap, which proved one of the most interesting items of the tour, thanks largely to the courtesy of the manager, Mr. J. Faull. A portion of the party stayed above ground viewing the surface plant, the process of tin dressing being lucidly explained by Mr. Faull. Seven of the party went underground with the underground manager, Mr. Lawry, and at the 395-fathom level had a good general view of the main features and conditions prevailing in a deep Cornish mine. A new lode recently discovered in a south cross-cut afforded an excellent example of a tin vein with well-defined walls; while visits to several ends and a rise above the 395-fathom level gave some idea of the high temperatures that have to be contended against in deep workings. Mr. Lawry's guidance and his fund of information made memorable this visit to a remarkably interesting mine. In the afternoon, proceeding to Camborne, a visit was paid to the School of Mines, where the party was met by Mr. E. H. Davison and Mr. H. R. Beringer, who showed the mineral collection and many of the fine recent acquisitions. From Camborne the cars proceeded to Great Work mine, Breage (tin, abandoned), where specimens of apatite, tourmaline, and greenish muscovite were found on the dumps. Thence to Penzance, via Germoe and Marazion, a short halt being made opposite St. Michael's Mount. At Penzance the party was met at the museum of the Royal Geological Society of Cornwall by the president, Mr. F. J. Stephens, and members of the council. After being entertained to tea, a most cordial address of welcome was given by Mr. Stephens, who reminded the visitors of the long series of illustrious mineralogists who had in the past been presidents of this the oldest scientific society in Cornwall. In replying

on behalf of the visitors, Sir John Flett thanked the Society for its welcome and declared that mineralogists, and in particular the foreign visitors, could not but be greatly impressed by the splendour and variety of the minerals of Cornwall. Mr. Arthur Russell, adding a further tribute of thanks, deplored the fact that there are nowadays so few collectors of minerals in the county, and that through the breaking up of estates, nearly every one of which had been the home of a mineral collection, these had been scattered and there were now few in Cornwall. Thus ended a week crowded with something of interest, one ventures to hope, to every member of the party; successful, too, from the point of view of the actual finding of minerals, rare and otherwise, which it was hoped would be found at the localities visited.

Northern Excursion.

Report by the Director, Prof. A. Hutchinson, F.R.S.

The members of the Northern Excursion left London (Euston station) on the morning of Thursday, September 23, for Cumberland. The party consisted of Professors R. Brauns (Bonn), S. Kreutz (Cracow), P. Niggli (Zürich), and F. Rinne (Leipzig), Drs. J. Drugman (Brussels), L. L. Fermor (Calcutta), L. J. Spencer (London), Messrs. J. W. Gruner (Minneapolis, Minnesota), A. F. Hallimond (London), W. Maucher (Munich), Lady Rachel Workman McRobert (Tarland, Aberdeenshire), and Professor A. Hutchinson (Cambridge), the leader of the party. The George Hotel, Penrith, was reached in the evening after an uneventful journey.

Friday, September 24.—Much rain fell in the night and we awoke to a wet and unpromising-looking morning. However, after breakfast the sky began to clear and, with the exception of Professor Brauns, who unfortunately felt obliged to return to London, we all started for Patterdale to examine the Greenside lead mine at Glenridding, Westmorland. On the way, a detour was made to visit Aira Force and an exposure of igneous rock in a road-metal quarry on the Troutbeck road just above the Fall. At the mine we were joined by one of our local members, Dr. W. Goodchild of the Threlkeld Sanatorium, and were welcomed by the manager, Mr. E. Borlase, who very kindly offered to take underground all those who wished to see the vein in situ. The majority of our party took advantage of this offer, and entering the mine by the Lucy Tongue level descended by shafts to the 120-fathom level, whence they brought fine specimens of crystallized galena from a strong vein

well exposed in the lowest workings. In the meantime, the rest were shown the dressing-plant and were busy on the dumps, where specimens of witherite, baryte, and blende were obtained. After tea at the Milcrest Hotel, Patterdale, some time was spent in admiring the scenery at the head of Lake Ullswater, seen to great advantage on a beautiful evening, and a quick run back to Penrith brought a pleasant day to a conclusion.

Saturday, September 25.—This morning we were joined by Mr. F. N. Ashcroft and Dr. H. von Eckermann, who had travelled up by the night

In the Shap Granite quarry, Westmorland.

[Dr. H. von Eckermann, Mr. W. Maucher, Dr. L. J. Spencer, Mr. A. F. Hallimond, Mr. J. W. Gruner, Dr. L. L. Fermor, Professor A. Hutchinson, Lady R. W. McRobert, Professor S. Kreutz.] *Photograph by* Mr. F. N. Ashcroft.

train, and our first objective was the Acorn Bank gypsum mine near Temple Sowerby, Westmorland. Here we were met by the owner, Mr. K. Boazman, who kindly took us over the mine and showed us grey massive gypsum some 20 feet thick with a layer of anhydrite about 2 feet thick at its base. We next visited another deposit, about a mile to the south-east, at Kirkby Thore, where the mineral was observed in an open working lying with an eroded and dissolved surface below a thin cover of glacial drift. Leaving the Eden valley and its Permian and Triassic red sandstones, we proceeded west over Carboniferous strata by Morland and Newby to Shap, Westmorland, to visit the famous Wasdale Crag quarry. Here we collected characteristic specimens of Shap granite, some showing pyrite and molybdenite on the joint-planes. Specimens of bismuthinite and baryte were also obtained. The so-called 'blue stone'

quarry, lying between the Wasdale Crag 'pink' quarry and the granite works, was also examined. The very extensive workings are in highly metamorphosed volcanic rock and afforded specimens showing garnet, epidote, actinolite, calcite, and pyrite. The return journey to Penrith was made by Bampton (to enable us to visit Hawes Water), Askham, and Lowther Park. In the evening Mr. and Mrs. C. S. Garnett joined the party.

Sunday, September 26.—A pleasant drive on a lovely morning took us to Grainsgill under Carrock Fell, Cumberland, by way of Mosedale and Mungrisdale, where a short halt was made to see Mr. J. Hemingway's collection of the local rocks. The morning was spent in examining the produce of the open workings in quartz veins in Grainsgill, and good specimens of wolframite, molybdenite, mispickel, and blende were obtained. Scheelite, tetradymite, bismuth, and apatite were also observed and specimens of granite and greisen collected. After lunch the majority of the party, under the guidance of Dr. W. Goodchild, who had joined us at Grainsgill, walked up Brandy Gill and down to the old workings in Dry Gill, where a find of some good campylites rewarded their exertions. A short climb, followed by a rough scramble down a stream bed, brought us to the head of Roughton Gill, but only a few poor specimens of pyromorphite could be seen on the old dumps. After an easy walk down the valley the cars were reached at Fell Side, and a direct run back to Penrith ended a profitable day made particularly enjoyable by perfect weather. In the evening we said good-bye to Dr. H. von Eckermann, who had to keep an appointment in Sheffield, and the next morning Mr. Hallimond was obliged to return to his duties in London.

Monday, September 27.—An eighteen-mile drive along the Eden valley brought us to the foot of the Pennine escarpment a little south of Roman Fell. At the works of the Long Fell Barytes Mines, Warcop, Westmorland, we were met by the manager, Mr. Craig, who showed and explained the process of preparing the flour barytes for the market. An hour's climb up the hill to an elevation of 1,750 feet found us at the mines, where five parallel veins ranging from 2 to 6 feet in width have been exploited by means of levels driven along their course. Into one of these we penetrated under the guidance of Mr. Brown, the underground manager, and although the deposit of large crystals which was discovered a few years ago was found to be exhausted, a number of typical specimens of baryte were collected. We next made our way over the fell to the head of the Hilton valley, where on the dumps of the old Scordale

mines yellow fluorite was found in abundance, though now unfortunately much weathered. After being photographed by Mr. Ashcroft, we rejoined the cars which had ascended the old mine track to meet us, and following a road running along the foot of the escarpment enjoyed on our homeward journey a splendid view of the sun setting behind the Lake District hills. Approaching Penrith, a detour was made to Eden Hall, 'Das Glück von Edenhall' being well remembered by the German members of the party.

Tuesday, September 28.—Before leaving Penrith we said good-bye to Professor Rinne, Mr. Gruner, and Mr. and Mrs. Garnett, who were unable to accompany us to Alston, but our diminished party was reinforced by Dr. Goodchild, who had come over from Threlkeld to join us. This morning we moved our head-quarters to Alston, Cumberland, travelling by way of the stone-circle known as 'Long Meg and her Daughters' near Little Salkeld to Melmerby, where the long ascent of the Pennine escarpment begins. Here a short halt was called to enable us to examine an igneous (doleritic) intrusion at the north end of the Cross Fell inlier, now being quarried for road-metal. Unfortunately the summit (Hartside Height) was shrouded in mist and we had no opportunity of enjoying the famous view, so pushing on to Alston we deposited our luggage at the Hill Crest Hotel. Our first destination in the Alston region was the Ayle Burn mine, where, by following directions kindly communicated to us by Mr. Arthur Russell, we were successful in finding excellent specimens of barytocalcite. Our next halt was called for lunch at the Nentsbury or Haggs mine near Nenthead, where, by the kindness of the manager, Mr. A. Treloar, we were able to visit the workings under the guidance of Mr. Liverick, the underground manager, and Mr. P. Blight. A trip of some two miles in the ore-wagons along a narrow level enabled us to see blende and witherite in situ, and these and specimens of epsomite and of baryte as small crystals (at first in the artificial light underground thought to be possibly hemimorphite) were collected. Very brilliant small black crystals of blende were abundant on the ore heap stacked outside the mine. The return journey to Alston was made by Blagill to enable us to visit the original barytocalcite locality, and further specimens of this mineral were obtained.

Wednesday, September 29.—Our final excursion necessitated an early start in the morning to enable us to reach the Boltsburn mine at Rookhope in Weardale, co. Durham, some twenty miles away, by 10 a.m. The route taken was by Nenthead (Cumberland), Coalcleugh and Allenheads (Northumberland), and in spite of the long and steep ascents which

had to be negotiated and some delay caused by a punctured tire we were only a few minutes late in arriving. At Boltsburn we were received by Mr. H. S. Willis, the general manager of the Weardale Lead Company, and were conducted to the workings by Mr. Thomas Maddison, the manager of the mine. After descending the shaft, a journey of over two miles was made in the ore-wagons along a level driven on the vein. A further descent followed by a short walk brought us to no. 3 Flat, one of the remarkable deposits of galena for which this mine is famous, which lie in the Great Limestone on either side of the vein and appear to be the result of metasomatic replacement. Here we found ourselves in a large room-like excavation, some 10 to 15 feet high, in which work was busily in progress. An examination of the walls revealed a mass of lenticles and strings of galena and also numerous cavities lined with brilliant cubo-octahedra of this mineral with which were associated cubes of fluorite and saddle-shaped crystallizations of chalybite or ferruginous dolomite. Much excellent collecting was done here, and it was with reluctance we tore ourselves away to follow our guide to other similar excavations in which we were rewarded by the sight of cavities lined with great cubes of fluorite measuring up to 6 or even 10 inches along their sides. The visit to these flats marked the culminating point of our excursion, and we could only regret that circumstances did not permit us to linger longer in this mineralogical treasure house. On leaving the mine Mr. Maddison kindly allowed us to inspect his beautiful collection of the local minerals. The return journey was made by St. John's Chapel and Wearhead, and the great dumps of fluorite stacked outside the Sedling mine were visited on the way. Alston was reached in ample time to pack our specimens and arrange for our several journeyings.

Mr. Ashcroft and Professor Kreutz returned to London the same evening. Early the next morning Lady McRobert and Dr. Fermor started for the Leadhills mines in Scotland, and Mr. Maucher for Frizington in west Cumberland. The four remaining members of the party, Professors Niggli and Hutchinson, Drs. Drugman and Spencer, set out for Cambridge, via Newcastle.

So ended an excursion rendered pleasant by the almost uniformly fine weather we enjoyed and made successful in its main object by the kindness of all the gentlemen who so readily allowed us to visit the mines and quarries under their control and assisted us with guidance and information.

Visit to Cambridge.

The final function in connexion with the Jubilee Celebrations was a visit to Cambridge undertaken by certain of the Society's guests and members on the invitation of Professor Hutchinson. During the course of Thursday, September 30, the following party assembled at Pembroke College, where the night was spent: Professors Kreutz, Niggli, and Rinne, Drs. Drugman, Burri, and Spencer, Messrs. Ashcroft, Melmore, and Tully. The next morning (October 1) the party attended in the Senate House to hear the valedictory address of the outgoing Vice-Chancellor, Dr. Seward, and to witness the installation of the new Vice-Chancellor, Mr. Weekes. The rest of the morning was occupied in visiting the University Library, the Library of the Cambridge Philosophical Society, and the Mineralogical Department and Museum. Here were shown the Sir Abraham Hume collection of diamonds (catalogued by de Bournon and presented by Viscount Alford in 1841), the H. J. Brooke collection, and many other treasures, including the only known crystal of the mineral stokesite. The Library of our Society, which has recently been completely overhauled by the new Librarian, Professor Hutchinson, was also inspected.

After lunch in the Old Library of Pembroke College, at which Dr. A. Harker and Dr. A. E. H. Tutton joined the party, the former conducted the members round the Sedgwick Museum, where they were received by Professor J. E. Marr, the Woodwardian Professor of Geology. Here, amongst many other things, they were shown the interesting and valuable old collection of Dr. John Woodward, a portion of which was bequeathed by him in 1728 to the University, the remainder (comprising the 'Foreign Fossils') being purchased in 1729. This collection is reverently preserved in the old cabinets in its original state. An adjournment was then made to the private laboratory of Dr. Tutton, recently built by him in the grounds of his house, where the party was kindly entertained to tea by Mrs. Tutton. Dr. Tutton afterwards demonstrated the unique collection of crystallographic apparatus contained in the laboratory.

During the brief but pleasant stay in Cambridge every chance opportunity was taken of pointing out to the foreign visitors the sights of the old University. This brought the proceedings to a conclusion, and the party dispersed to London and elsewhere in the evening.

Addresses and Letters of Congratulation.

Formal addresses were not expected, and they are consequently few in number. Delegates had been invited only from closely allied foreign societies, of which there are but few. The Mineralogical Societies of France, Germany, Switzerland, and America each sent one or two delegates, the only other publishing Mineralogical Societies not represented by delegates being those of Russia and Vienna (messages from these two are given below). Delegates were also sent by the Geological Societies of Sweden, Poland, and Cornwall. Most of the invitations had been sent to individuals, but owing to the distance and, in some countries, to the difference of monetary exchange, the number of acceptances was not large. These include distinguished mineralogists from Finland, France, Germany, Spain, and the United States of America, and to them special thanks are due. Some others (from Norway, Hungary, and Portugal) who had intended to come were unfortunately detained at the last moment. Cordial letters regretting inability to attend, and in most instances conveying congratulations and good wishes to the Society, were received from the following gentlemen :

Prof. Charles Barrois, University of Lille.
Prof. F. Becke, University of Vienna.
Senhor Antonio Maria de Oliveira Bello, Lisbon.
Prof. O. B. Bøggild, Copenhagen.
Prof. P. N. Chirvinsky, Novocherkassk, Russia.
Prof. G. D'Achiardi, University of Pisa.
Prof. E. S. Dana, New Haven, Connecticut.
Dr. H. V. Ellsworth, Geological Survey of Canada, Ottawa.
Prof. G. Friedel, University of Strasbourg, Alsace.
Prof. Victor Goldschmidt, Heidelberg.
Prof. V. M. Goldschmidt, Oslo, Norway.
Prof. R. P. D. Graham, McGill University, Montreal, Canada.
Prof. F. Grandjean, President of the French Mineralogical Society.
Prof. P. von Groth, Munich.
Prof. J. E. Hibsch, Vienna.
Prof. J. Koenigsberger, Freiburg, Baden.
Dr. L. Kulik, Mineralogical Museum, Academy of Sciences, Petrograd.
Dr. G. F. Kunz, President of the New York Mineralogical Club.
Prof. A. Lacroix, Natural History Museum, Paris.
Dr. H. Michel, Natural History Museum, Vienna.

Prof. J. Morozewicz, Director of the Geological Survey of Poland, Warsaw.

Prof. V. Rosický, Masaryk University, Brno, Moravia.

Dr. W. T. Schaller, President of the Mineralogical Society of America, Washington, D.C.

Prof. F. Slavík, Bohemian University, Prague.

Dr. S. Stevanović, Belgrade.

Prof. G. von Tschermak, Vienna.

Prof. W. Vernadsky, Petrograd.

Prof. L. Weber, Freiburg, Switzerland.

Prof. F. Zambonini, University of Naples.

Dr. K. Zimányi, Hungarian National Museum, Budapest.

Telegrams received during the meeting include the following:

From Prof. P. von Groth, Munich.—

Der Mineralogischen Gesellschaft sendet zum 50. Jubiläum herzliche Glückwünsche und Grüsse, bedauernd an der Feier nicht teilnehmen zu können, P. Groth.

From Prof. František Slavík, Prague.—

I beg to greet all my British friends and tender my best congratulations to the Society for glorious past and future.

From Prof. V. M. Goldschmidt, Oslo.—

The Mineralogical Institute congratulates and sends the best wishes.

From Prof. G. Aminoff and Dr. N. Zenzén, Stockholm.—

G. Aminoff and N. Zenzén of the Mineralogical Department of the State Natural History Museum at Stockholm send their best congratulations to the Jubilee of the Mineralogical Society.

From the Russian Mineralogical Society, Petrograd.—

Russian Mineralogical Society send Mineralogical Society, London, sincerest wishes further progress successful activity.

President Karpinsky. Secretary Gerassimov.

Formal addresses and extracts from letters are as follows:

The Royal Geological Society of Cornwall.—

The Royal Geological Society of Cornwall sends greetings to the Mineralogical Society and hearty congratulations on the occasion of its Jubilee. The science of mineralogy has always attracted Cornishmen and the Society can claim many members who were mineralogists of repute. The two Societies can also claim the late Mr. J. H. Collins, who was in turn Secretary and President of the Royal Geological Society of Cornwall, and one of the founders of the Mineralogical Society. It is therefore with special pleasure that the Society congratulates the Mineralogical Society on the great value of the work it has done during the past

fifty years, and expresses the hope that its efforts towards the advancement of the science may be still more successful in the future.

Ernest H. Davison, Hon. Sec. Francis J. Stephens, President.

Polskie Towarzystwo Geologiczne (The Polish Geological Society), Kraków.—

To the President and Council of the Mineralogical Society.

The Polish Geological Society behold, with sincere admiration, the results of half a century's work of the Mineralogical Society, which has achieved success not only in working on the mineralogical investigation of its native country, but also in collaborating fruitfully towards the solution of worldwide problems in the field of crystallography, mineralogy, and petrology. In all these domains, the Mineralogical Society has been in the first rank of the workers of many nations, in harmonious fellowship of common effort with them all.

With the help of its excellent organ, the Mineralogical Magazine, the Society is rendering most valuable services to scientific research by registering accurately all notable facts which are taking place in mineralogical work throughout the world. It gives us particular pleasure to acknowledge on this occasion that the efforts and achievements of Polish mineralogists also receive their share of notice in the pages of the Magazine.

The Polish Geological Society joins in the jubilee celebrations of the Mineralogical Society with all the greater ardour because the Mineralogical Society has always remained mindful of the close connexion between the sister sciences of mineralogy and geology. Best proof of this is furnished by the publication of the geological and mineralogical maps issued in the volumes of the Magazine.

The Polish Geological Society, which comprises in its ranks also all the research workers in the field of mineralogy in Poland, begs to give expression to its warmest and most sincere feelings at the moment of the jubilee of the Mineralogical Society, and it offers the Society its best wishes for further prosperous progress in its meritorious work.

The Secretary, Dr. Bieda. The President, Jan Nowak.

Magyar Nemzeti Muzeum (Hungarian National Museum), Budapest.—

To the President and Council of the Mineralogical Society in London.

Gentlemen.

The Magyar Nemzeti Muzeum (Hungarian National Museum) desires to offer its best wishes and heartiest congratulations on the occasion of the Semicentennial Jubilee of the Mineralogical Society.

The Hungarian Mineralogists highly appreciate the progress and value of the research work accomplished by the British members of the Society.

The Mineralogical Magazine, this standard periodical, is well known wherever Mineralogy is cultivated.

It is a great pleasure to us to express our best wishes for future prosperity and further successful progress of the Mineralogical Society.

Zimányi Károly,
Director of the
Mineralogical Department.

Prof. Dr. Hóman,
Director of the
Magyar Nemzeti Muzeum.

Wiener Mineralogische Gesellschaft (Vienna Mineralogical Society).—

An die Mineralogical Society, London.

Mit reger Teilnahme erhielt die Wiener Mineralogische Gesellschaft die ehrenvolle Einladung zu der Jubiläumsfeier der Gründung der Mineralogical Society im September 1926. Leider erlaubten die Umstände nicht einen Vertreter zu der Festfeier nach London zu entsenden. Doch möchten wir nicht versäumen wenigstens auf schriftlichem Wege unsere herzlichen Glückwünsche dar zu bringen.

Durch ein halbes Jahrhundert hat die Mineralogical Society dank dem Scharfsinn und dem unermüdlichen Eifer ihrer Mitglieder, unterstützt durch den Reichtum der Sammlungen und die über den ganzen Erdkreis ausgespannten Beziehungen des Grossbritannischen Weltreichs, die Mineralogie mit reichen Ergebnissen gefördert.

Die Wiener Mineralogische Gesellschaft beglückwünscht die Mineralogical Society zu dieser glanzvollen Vergangenheit; sie ist überzeugt, dass die Gesellschaft auch in den kommenden Decennien sich nicht minder segensreich für die Mineralogen des ganzen Erdkreises bewähren werde und begrüsst die Mineralogical Society für alle Zukunft mit dem alten deutschen Bergmanns-Spruch: 'Glück auf!'

Dr. Arthur Marchet, Schriftführer. Friedrich Becke, Präsident.

From Prof. Victor Goldschmidt, Heidelberg.—

An den Präsidenten der Mineralogical Society, London. Verehrter Herr Präsident:

Sie hatten die Güte, mich zu dem schönen Fest Ihres 50jährigen Jubiläums einzuladen, wofür ich aufrichtig danke. Leider kann ich persönlich nicht erscheinen, möchte aber meine besten Wünsche senden für das weitere Blühen der Gesellschaft, die zur Förderung unserer Wissenschaft so viel beigetragen hat.

Mit der Mineralogical Society bin ich aufs engste verbunden, da sie mir 1912 die Ehre erwiesen hat, mich zu ihrem Ehrenmitglied zu machen.[1]

Mein wissenschaftlicher Lebenslauf geht parallel mit dem der Gesellschaft. Als sie 1876 gegründet wurde, habe ich meine erste wissenschaftliche Arbeit geschrieben, die 1877 in Fresenius Zeitschrift erschienen ist und heute, nach 50 Jahren, stehe ich noch arbeitsfreudig im Dienst unserer geliebten Wissenschaft.

Unsere Wissenschaft hat zur Entdeckung grosser Gesetze geführt, die nicht nur die Krystallformen beherrschen, sondern der Mannigfaltigkeit in der gesamten Natur ihre Wege vorschreiben. Wenn es mir nun vergönnt war, die Gesetze der Entwicklung der Krystallformen bei den Farben der Kunst und den Tönen der Musik sowie in anderen Gebieten wiederzufinden, so verdanke ich dies unserer hohen Wissenschaft.

Mir will scheinen, als ob, wie früher die Astronomie, heute die Krystallographie berufen sei die Führung unter den Naturwissenschaften zu übernehmen. Um so hohem Ziel zuzustreben, reicht die Kraft und Lebensdauer des Einzelnen

[1] Also an Ordinary Life Member since 1886.

nicht aus und es ist ein grosses Verdienst der Begründer der Mineralogical Society, dass sie unter Verschmelzung mit der Crystallological Society vor 50 Jahren die Kräfte Englands vereinigt und die des Auslands zur Mitarbeit herangezogen hat. Bald darauf entstand die französische Mineralogische Gesellschaft, später die Wiener und die Deutsche Mineralogische Gesellschaft. Nun sind auch die Amerikaner auf dem Platz erschienen. Die anderen Länder werden folgen. Zwischen diesen Gesellschaften besteht ein internationaler Verband, der, unbekümmert um die leidige Politik, alle vereinigen soll, die den gleichen Zielen zustreben.

England aber mit seiner Mineralogical Society darf sich rühmen, den Weg eröffnet zu haben, wofür die Welt ihm dankbar ist.

Genehmigen Sie als Zeichen der Verehrung ein Exemplar der von mir herausgegebenen „Beiträge zur Krystallographie und Mineralogie" zu überreichen (soweit erschienen), sowie meine erste Publikation (1877) und die letzte (1925), mit der Bitte dieselben Ihrer Bibliothek einzureihen.[1]

In alter Ergebenheit

Dr. Victor Goldschmidt.

From Prof. F. Zambonini, Istituto di Chimica Generale, R. Università di Napoli.—

J'apprécie dans toute sa valeur votre invitation, et j'aurais été bien heureux de me rendre à Londres pour rendre hommage à la Société Minéralogique Anglaise, qui a tant de titre de gloire et peut justement être fière d'avoir eu et de compter encore aujourd'hui des savants à qui nous sommes redevables de bien de progrès dans nos études. Il m'eût été très-agréable aussi de connaître personnellement les minéralogistes anglais, dont j'apprécie les travaux, dans lesquels j'ai appris beaucoup : ces minéralogistes qui sont les dignes successeurs de Whewell, de Wollaston, de Brewster, de Miller, pour ne nommer que ceux qui nous ont appris la cristallographie, nous ont donné les moyens de mesurer exactement les cristaux, et ont bâti les fondements de l'optique des cristaux.

Mais avec un très-grand regret, dans les conditions actuelles de la monnaie italienne, je pense que c'est un devoir de bon citoyen, de suivre le désir du Gouvernement italien, c'est-à-dire que l'argent italien ne doit être depensé à l'étranger qu'en cas de nécessité.

Je suis sûr que vous sauriez apprécier ma décision de ne pas me rendre à Londres et que vous comprenez parfaitement mon regret de ne pas pouvoir exprimer personnellement à mes collègues anglais mes sentiments d'admiration pour leur œuvre scientifique, mes vœux les plus sincères pour l'avenir de la Mineralogical Society. Je vous prie de vouloir bien vous rendre interprète de mes sentiments.

[1] Beitr. Kryst. Min., vol. 1 (1914–19), vol. 2 (1919–24), vol. 3, pt. 1 (1926).

V. Goldschmidt (Assistent a. d. Königl. Bergakademie zu Freiberg), Ueber Bestimmung des Gewichtes kleiner Silber- und Goldkörner mit Hülfe des Mikroskopes. Zeits. analyt. Chem., 1877, vol. 16, pp. 434–448.

V. Goldschmidt, Materialien zur Musiklehre (2 vols., Heidelberg, 1925).

These volumes were specially bound for the occasion and supplied with a printed dedication : Der Mineralogical Society London zu ihrem 50jährigen Jubiläum 1876–1926 überreicht von Victor Goldschmidt, Heidelberg.

From Prof. G. D'Achiardi, University of Pisa.—

Sono grato dell'invito e spiacente di non potere intervenire alla celebrazione del 50° anniversario della Mineralogical Society.

La prego quindi volere scusare la mia assenza e gradire i più vivi auguri di lunga e prospera vita per la Società, così meritoria del progresso degli studii mineralogici.

È con particolare commozione che io ricordo che il compianto mio genitore ricevette la nomina a membro onorario della Min. Soc. pochi giorni prima della sua morte, e che questo insigne riconoscimento dei suoi meriti consolò gli ultimi giorni della sua vita!

From Prof. P. N. Chirvinsky, Dean of the Mining Faculty, Don Polytechnic Institute, Novocherkassk, South Russia.—

Г-ну Президенту Британского Минералогического Общества, профессору В. В. Ваттсу.

Глубокоуважаемый господин Президент!

По поручению Совета Горного Факультета Донского Политехнического Института имею честь приветствовать Вас и Британское Минералогическое Общество по поводу 50-ти летнего юбилея его славного существования. За пятьдесят лет кристаллография, минералогия и петрография шагнули далеко вперед и в общем еще теснее связались с такими основными науками, как математика, физика и химия. Просматривая работы, собранные в томах печатного органа Общества на протяжении десятков лет, можно ясно проследить эту эволюцию. Не все старое однако старест—фактическая основа, точный эксперимент или наблюдение, точная цифра и число не теряют никогда своего значения. К такого рода точности в своих работах стремились всегда члены Британского Минералогического Общества. Девизом журнала Mineralogical Magazine было всегда: не много по количеству, но много по качеству или как кратко говорили римляне non multa, sed multum. Это громадная заслуга Британского Минералогического Общества, дух которого неизменно поддерживается в суровой простоте, оно, как наездник, умеющий держать горячего коня на мундштуке, чтобы ровно и верно итти к цели. Нельзя не приветствовать далее того этапа эволюции научной жизни Общества, который выразился в расширении рефератной части его печатного органа: так можно шире взглянуть на весь ход близких всем нам наук в разных странах, так можно лучше каптировать отдельные ювенильные струи творчества, чтобы со временем сливать их в один общий неудержимый поток, долженствующий двигать человечество к лучшему будущему. Процветания Вашему Обществу желает горячо Горный Факультет Донского Политехнического Института.

С своей стороны я тем более рад исполнить волю возглавляемого мною Горного Факультета и его Совета, что сам имею честь сотрудничать в журнале Британского Минералогического Общества и тем могу внести свою лепту в дело сближения русской и английской науки.

Да здравствует Британское Минералогическое Общество на многие лета!

Примите, господин Президент, уверение в моем глубоком

к Вам уважении и преданности,

П. Чирвинский, проф. и декан Горного Факультета ДПИ.

Translation of Prof. P. N. Chirvinsky's letter (kindly supplied by Colonel N. T. Belaiew).—

To the President,
The British Mineralogical Society,
Professor W. W. Watts.

Dear Mr. President,

On behalf of the Senate of the Faculty of Mining of the Donskoy Polytechnic Institute, I have the honour to greet you and the British Mineralogical Society on the occasion of the fiftieth Jubilee of its glorious existence.

During the span of fifty years crystallography, mineralogy, and petrography have made great strides forward, and in general have come into yet more intimate contact with such bed-rock sciences as mathematics, physics, and chemistry. When one is looking through the publications gathered in the volumes of the Journal of the Society for tens and tens of years, it is easy to see this evolution. But not everything of the past is becoming old—for instance, the facts, the accurate experiments or observation, the accurate figures or ratios never lose their meaning. It is such kind of accuracy which the members of the British Mineralogical Society have been striving for in their works. The motto of the Mineralogical Magazine has been always: 'Not too much in quantity, but rather much in quality', or as the Romans put it concisely: 'Non multa, sed multum.'

It is a tremendous service which is rendered by the British Mineralogical Society, whose spirit is always kept in an austere simplicity. It is like a rider who understands how to master his spirited steed and guide it straight and calmly to its goal.

We cannot refrain from praising also the recent step in the development in the scientific life of the Society, which manifested itself in enlarging the review part of the journal. That enables one to have a wider outlook on the progress of the neighbouring sciences in different countries. It enables one also to capture better the different rivulets in order to bring them together in time into one irresistible stream which ought to take humanity towards its better future.

The Faculty of Mines of the Donskoy Polytechnic Institute most heartily wishes prosperity to your Society. On my own behalf I am the more glad to fulfil the request of the Faculty of Mines and of its Senate over which I am presiding, as I have myself had the honour to be a contributor to the Journal of the British Mineralogical Society, and thus I was able to contribute my mite to the work of bringing together Russian and English sciences.

Live the British Mineralogical Society for ever and ever.

I beg, Mr. President, to ask you to accept my expressions of my highest esteem.

From Prof. W. Vernadsky, Petrograd.—

I beg you to express my best wishes to the Mineralogical Society whose work is so important for the progress of science. I am sorry that it is impossible for me to come and take part with my English friends in the meetings of these historical days.

From Dr. L. Kulik, Meteorite Dept., Mineralogical Museum, Academy of Sciences, Petrograd.—

Circumstances having prevented me from profiting by this kind invitation I beg you to forward my hearty wishes of further prosperity to the Society which has been honourably carrying on the scientific work for the use of all humanity in the course of half a century.

Prof. Gustav von Tschermak, Vienna.—

I am very much indebted for the cordial invitation to attend the celebration of the Jubilee of the British Mineralogical Society of which I am proud to be Honorary Member. I thank you for this honour as also for the kindly offered hospitality during the celebration in London. Therefore I am very sorry to be hindered by my age of ninety years to attend the celebration which as I wish will take a very satisfying course.

Prof. F. Becke, The University, Vienna.—

Leider gestatten die Verhältnisse mir nicht der Einladung Folge zu geben. Um so mehr fühle ich mich gedrängt der Mineralogical Society nebst meinem ergebensten Dank meine herzlichsten Glückwünsche für die zukünftige erfolgreiche Wirksamkeit zum Ausdruck zu bringen, die sich vereint mit der aufrichtigen Bewunderung und Anerkennung des im abgelaufenen halben Jahrhundert von Ihr Geleisteten.

From Dr. H. Michel, Natural History Museum, Vienna.—

Indem ich nochmals herzlichst danke, erlaube ich mir die besten Wünsche zu der Feier des 50jährigen Bestandes Ihrer Gesellschaft, sowohl im Namen der Mineralogisch-Petrographischen Abteilung des Naturhistorischen Museums in Wien sowie im eigenen Namen zu übermitteln.

List of Delegates, Guests, and Members

taking part in the Jubilee Celebration.

R. Allen, Imperial Institute, London.
Dr. H. M. Ami, Ottawa, Canada.
F. N. Ashcroft, London.
W. T. Astbury, Royal Institution, London.
T. V. Barker, University Museum, Oxford.
George Barrow, London.
Dr. F. A. Bather, F.R.S., British Museum (Natural History), President of the Geological Society of London.
Colonel N. T. Belaiew, C.B., London.
*Prof. J. L. H. Borgström, University of Helsingfors, Finland.
Prof. P. G. H. Boswell, University of Liverpool.
Prof. H. L. Bowman, University of Oxford.
Sir William H. Bragg, K.B.E., F.R.S., Royal Institution, London.

* Delegates and Invited Guests.

Dr. A. Brammall, Imperial College of Science, London.
*Prof. R. Brauns, University of Bonn, Germany.
J. Broadhead, Darlington.
A. J. Bull, President of the Geologists' Association, London.
Dr. C. R. Burri, Freiburg, Baden.
Henry Buschor, Barcelona, Spain.
F. H. Butler, London.
Dr. W. A. Caspari, Royal Institution, London.
*Prof. Frank Wigglesworth Clarke, Washington, D.C., U.S.A. (Honorary Member).
H. Collingridge, Romford, Essex.
T. Crook, Imperial Institute, London.
Prof. C. G. Cullis, Imperial College of Science, London.
Dr. H. H. Dale, F.R.S., Secretary of the Royal Society, London.
*E. H. Davison, Camborne, Delegate of the Royal Geological Society of Cornwall.
H. Dewey, Geological Survey of Great Britain, London.
*Dr. J. Drugman, Brussels, Delegate of the French Mineralogical Society.
*Prof. L. Duparc, University of Geneva, Delegate of the Swiss Mineralogical Society.
Dr. A. R. Dwerryhouse, Caversham, Oxfordshire.
*Dr. H. von Eckermann, Delegate of the Geological Society of Sweden.
Dr. J. W. Evans, F.R.S., Imperial College of Science, London.
Dr. L. L. Fermor, Geological Survey of India, Calcutta.
Sir John S. Flett, F.R.S., Director of the Geological Survey of Great Britain, London.
*Joaquin Folch y Girona, Barcelona, Spain.
C. S. Garnett, Derby.
Mrs. C. S. Garnett, Derby.
Dr. W. Goodchild, Threlkeld Sanatorium, Cumberland.
H. S. Gordon, London.
*Samuel G. Gordon, Delegate of the Academy of Natural Sciences of Philadelphia, U.S.A., and of the Mineralogical Society of America.
*Prof. B. Gossner, University of Munich, Germany.
J. F. N. Green, London.
G. Greenwood, University of Manchester.
A. G. F. Gregory, London.
J. W. Gruner, University of Minnesota, Minneapolis, U.S.A.
A. F. Hallimond, Museum of Practical Geology, London.
Dr. A. Harker, F.R.S., Cambridge.

Dr. H. F. Harwood, Imperial College of Science, London.
Dr. F. H. Hatch, Mines Department, London.
H. Heertz, Frankfurt a. M., Germany.
Prof. H. Hilton, Bedford College, London.
Sir Thomas H. Holland, K.C.S.I., K.C.I.E., F.R.S., Rector of the Imperial College of Science, London.
J. A. Howe, Geological Survey of Great Britain, London.
Prof. A. Hutchinson, F.R.S., University of Cambridge, Director of the Northern Excursion.
R. W. James, University of Manchester.
S. J. Johnstone, Imperial Institute, London.
A. E. Kitson, Director of the Geological Survey of the Gold Coast.
Dr. I. E. Knaggs, Royal Institution, London.
*Prof. Stefan Kreutz, Delegate of the Polish Academy of Sciences, and of the Polish Geological Society, Cracow.
Prof. A. Liversidge, F.R.S., Kingston, Surrey.
A. D. Lumb, London.
C. McDermid, Secretary of the Institution of Mining Engineers, London.
Dr. W. F. P. McLintock, Curator of the Museum of Practical Geology, London.
Lady Rachel Workman McRobert, Tarland, Aberdeenshire.
G. S. W. Marlow, Secretary of the Faraday Society, London.
W. Maucher, Munich, Germany.
Dr. E. T. Mellor, Johannesburg, Transvaal.
S. Melmore, York.
Sir Henry A. Miers, F.R.S., Trustee of the British Museum, London.
H. B. Milner, Imperial College of Science, London.
E. D. Mountain, British Museum (Natural History), London.
*Prof. P. Niggli, University of Zürich, Delegate of the Swiss Mineralogical Society.
B. Orelkin, Royal Institution, London.
Dr. R. L. Parker, Mineralogical Institute, Zürich, Switzerland.
Dr. John Parkinson, London.
Dr. G. T. Prior, F.R.S., Keeper of the Mineral Department, British Museum (Natural History), London.
G. M. Puckle, Eversley, Hampshire.
Dr. W. A. Richardson, Principal of the School of Science and Art, Newark-on-Trent.
*Prof. F. Rinne, University of Leipzig, Delegate (President) of the German Mineralogical Society.

Sir Robert Robertson, F.R.S., Government Laboratory, London.
A. Russell, Swallowfield Park, Reading, Director of the Southern Excursion.
Dr. G. F. Herbert Smith, British Museum (Natural History), London.
W. Campbell Smith, British Museum (Natural History), Secretary of the Geological Society of London.
Dr. L. J. Spencer, F.R.S., British Museum (Natural History), London.
*Dr. H. Steinmetz, University of Munich, Germany.
*F. J. Stephens, Camborne, Delegate of the Royal Geological Society of Cornwall.
W. E. Swinton, British Museum (Natural History), London.
J. C. Taylor, London.
Dr. H. H. Thomas, Geological Survey of Great Britain, London.
S. I. Tomkeieff, Armstrong College, Newcastle-on-Tyne.
B. J. Tully, London.
Dr. A. E. H. Tutton, F.R.S., Cambridge.
*Dr. H. Ungemach, Paris, France.
J. W. Walker, Toronto, Canada.
*Prof. T. L. Walker, University of Toronto, Delegate of the Mineralogical Society of America.
Prof. W. W. Watts, F.R.S., Imperial College of Science, London.
Kathleen Yardley, Royal Institution, London.

Officers of the Mineralogical Society (1876–1926).

Presidents.

1876–79	Henry Clifton Sorby, *F.R.S.*
1879–81	Matthew Forster Heddle, *M.D.*
1881–83	Wilfred Hudleston Hudleston, *F.R.S.*
1883–85	Thomas George Bonney, *F.R.S.*
1885–88	*Sir* Lazarus Fletcher, *F.R.S.*
1888–91	Robert Henry Scott, *F.R.S.*
1891–98	Mervyn Herbert Nevil Story-Maskelyne, *M.P.*, *F.R.S.*
1898–1901	*Sir* Arthur Herbert Church, *K.C.V.O.*, *F.R.S.*
1901–04	Hugo Heinrich Wilhelm Müller, *F.R.S.*
1904–09	*Sir* Henry Alexander Miers, *F.R.S.*
1909–12	William James Lewis, *F.R.S.*
1912–15	Alfred Edwin Howard Tutton, *F.R.S.*
1915–18	William Barlow, *F.R.S.*
1918–21	*Sir* William Phipson Beale, *Baronet*, *K.C.*, *M.P.*

1921–24	Arthur Hutchinson, *F.R.S.*
1924–	William Whitehead Watts, *F.R.S.*

Vice-Presidents.

1876-97	Samuel Haughton, *F.R.S.*
1876–79	Matthew Forster Heddle, *M.D.*
1879–83	Thomas George Bonney, *F.R.S.*
1883–88	Wilfred Hudleston Hudleston, *F.R.S.*
1888–1901	Hugo Heinrich Wilhelm Müller, *F.R.S.*
1897–1898	*Sir* Arthur Herbert Church, *K.C.V.O.*, *F.R.S.*
1898–1908	George Downing Liveing, *F.R.S.*
1901–04	*Sir* Henry Alexander Miers, *F.R.S.*
1904–09	William James Lewis, *F.R.S.*
1908–12	Alfred Edwin Howard Tutton, *F.R.S.*
1909-24	Herbert Lister Bowman, *D.Sc.*
1912–21	Arthur Hutchinson, *F.R.S.*
1921–25	Herbert Henry Thomas, *Sc.D.*
1924–	Harold Hilton, *D.Sc.*
1925–	*Sir* Thomas Henry Holland, *K.C.S.I.*, *K.C.I.E.*, *F.R.S.*

Treasurers.

1876–85	Robert Philips Greg.
1885–91	Thomas George Bonney, *F.R.S.*
1891–1901	Frederick William Rudler.
1901–02	Charles Alexander McMahon, *F.R.S.*, *Lieutenant-General.*
1902–18	*Sir* William Phipson Beale, *Baronet*, *K.C.*, *M.P.*
1918–24	John William Evans, *F.R.S.*
1924–	Frederick Noel Ashcroft.

General Secretaries.

1876–81	Joseph Henry Collins.
1881–88	Robert Henry Scott, *F.R.S.*
1888–1909	*Sir* Lazarus Fletcher, *F.R.S.*
1909–	George Thurland Prior, *F.R.S.*

Foreign Secretaries.

1876–84	*Sir* Clement Le Neve Foster, *F.R.S.*
1884–92	Thomas Davies.
1892–1906	John Wesley Judd, *F.R.S.*
1906–1924	William Whitehead Watts, *F.R.S.*
1924–	John William Evans, *F.R.S.*

Editors of the Journal.

1876–81	The General Secretary [J. H. Collins].
1881–88	„ „ „ [R. H. Scott].
1888–91	„ „ „ [*Sir* L. Fletcher].
1891–1900	*Sir* Henry Alexander Miers, *F.R.S.*
1900–	Leonard James Spencer, *F.R.S.*

Trustees.

1876–89	William Bernard de Blaquiere, *5th Baron de Blaquiere.*
1876–94	Patrick Dudgeon.
1889 1911	Mervyn Herbert Nevil Story-Maskelyne, *M.P.*, *F.R.S.*
1894–1916	Robert Henry Scott, *F.R.S.*
1911–	*Sir* Henry Alexander Miers, *F.R.S.*
1911–	Friedrich Noel Ashcroft Fleischmann, *afterwards* Frederick Noel Ashcroft.

Librarians.

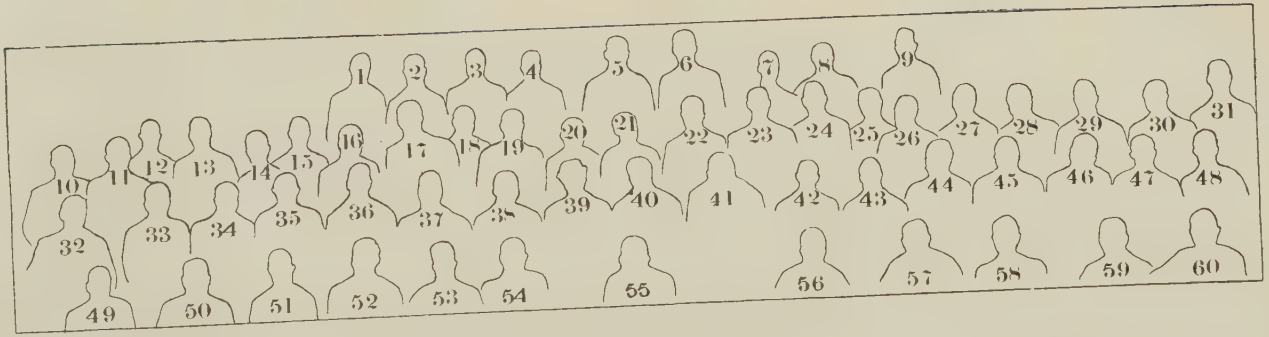
1876–81	The General Secretary [J. H. Collins].
1881–89	Frederick William Rudler.
1889–1925	William James Lewis, *F.R.S.*
1925–	Arthur Hutchinson, *F.R.S.*

Honorary Members* (1877–1926).

Baumhauer, Heinrich, *Freiburg, Switzerland* (1905-26).
Becke, Friedrich Johann, *Vienna* (1909–).
Bertrand, Émile, *Paris* (C–1909).
Brezina, Maria Aristides, *Vienna* (1895–1909).
Brøgger, Waldemar Christofer, *Christiania = Oslo* (1895–).
Brush, George Jarvis, *New Haven, Connecticut* (1879–1912).
Calderón y Arana, Salvador, *Madrid* (1909–11).
Cesàro, Giuseppe, *Liége* (1909–).
Clarke, Frank Wigglesworth, *Washington, D.C.* (1913–).
Cotta, Carl Bernhard *von, Freiberg, Saxony* (1879).
D'Achiardi, Antonio, *Pisa* (1902).
Dana, Edward Salisbury, *New Haven, Connecticut* (1897–).
Dana, James Dwight, *New Haven, Connecticut* (1877–95).

* Termed Corresponding Members until 1900. C denotes Corresponding Member of the Crystallological Society; these (three) were elected Corresponding Members of the Mineralogical Society on February 12, 1884, following the amalgamation of the two Societies on December 11, 1883.

Daubrée, Gabriel Auguste, *Paris* (1879–96).
Delesse, Achille Ernest Oscar Joseph, *Paris* (1879–81).
Des Cloizeaux, Alfred Louis Olivier Legrand, *Paris* (1879–97).
Esmark, *Pastor*, *Christiania* (1877–82).
Fedorov, Evgraf Stepanovich, *St. Petersburg* (1910–1919).
Fouqué, Ferninand André, *Paris* (1898–1904).
Geinitz, Hanns Bruno, *Dresden* (1879–1900).
Goldschmidt, Victor, *Heidelberg* (1912–). [Also an Ordinary Life Member since 1886.]
Groth, Paul Heinrich *von*, *Munich* (1877–)
How, Henry, *Windsor*, *Nova Scotia* (1877–79).
Johnstrup, Johannes Frederik, *Copenhagen* (1877–94).
Kjerulf, Theodor, *Christiania* (1877–88).
Klein, Johann Friedrich Carl, *Berlin* (1895–1907).
Kobell, Wolfgang Xaver Franz *von*, *Munich* (1879–82).
Lacroix, Antoine François Alfred, *Paris* (1900–).
Lang, Victor *von*, *Vienna* (C–1921).
Lévy, Auguste Michel, *Paris* (1898–1911).
Liebisch, Theodor, *Berlin* (1903–22).
Ludwig, Ernst, *Vienna* (1883–1915).
Moissenet, Vivant Léon, *Paris* (1877–1906).
Nordenskiöld, *Baron* Nils Adolf Erik, *Stockholm* (1877–1901).
Penfield, Samuel Lewis, *New Haven*, *Connecticut* (1904–06).
Rammelsberg, Carl Friedrich August, *Berlin* (1879–99).
Rath, J. J. Gerhard *vom*, *Bonn* (1879–88).
Renard, Alphonse François, *Brussels* (1879–1903).
Romanovsky, Nikolai Maximilianovich, *Grand Duke of Leuchtenberg*, *St. Petersburg* (C–1891).
Rosenbusch, Karl Harry Ferdinand, *Heidelberg* (1879–1914).
Sandberger, Karl Ludwig Fridolin *von*, *Würzburg* (1879–98).
Sella, Quintino, *Rome* (1879–84).
Steenstrup, Knud Johannes Vogelius, *Copenhagen* (1877–1913).
Struever, Johannes Karl Theodor, *Rome* (1903–15).
Tschermak, Gustav *von*, *Vienna* (1879–).
Viola, Carlo Maria, *Parma* (1912–25).
Waage, Peter, *Christiania* (1877–1900).
Wallerant, Frédéric, *Paris* (1913–).
Wiik, Fredrik Johan, *Helsingfors* (1880–1909).
Zirkel, Ferdinand, *Leipzig* (1879–1912).



KEY TO GROUP (Plate II).

Back row.

1. Mr. W. Campbell Smith.
2. Dr. H. H. Thomas.
3. Dr. G. F. Herbert Smith.
4. Prof. H. L. Bowman.
5. Mr. F. N. Ashcroft.
6. Dr. C. R. Burri.
7. Mr. J. Broadhead.
8. Mr. J. A. Howe.
9. Mr. C. S. Garnett.

Second row.

10. Mr. A. J. Bull.
11. Mr. J. W. Gruner.
12. Mr. A. F. Hallimond.
13. Dr. W. F. P. McLintock.
14. Mr. S. G. Gordon.
15. Mr. B. J. Tully.
16. Col. N. T. Belaiew.
17. Dr. H. von Eckermann.
18. Dr. H. Steinmetz.
19. Dr. L. J. Spencer.
20. Dr. F. H. Hatch.
21. Dr. F. A. Bather.
22. Prof. A. Hutchinson.
23. Mr. E. H. Davison.
24. Dr. L. L. Fermor.
25. Mr. W. Maucher.
26. Dr. A. E. H. Tutton.
27. Sir T. H. Holland.
28. Sir J. S. Flett.
29. Mr. J. Folch y Girona.
30. Mr. W. J. Anderson.
31. Mr. J. C. Taylor.

Third row.

32. Dr. A. R. Dwerryhouse.
33. Prof. S. Kreutz.
34. Prof. J. L. H. Borgström.
35. Prof. B. Gossner.
36. Prof. T. L. Walker.
37. Prof. P. Niggli.
38. Sir H. A. Miers.
39. Sir David Prain.
40. Lord Ullswater.
41. Lord Rothschild.
42. Prof. W. W. Watts.
43. Dr. G. T. Prior.
44. Prof. F. Rinne.
45. Prof. R. Brauns.
46. Prof. L. Duparc.
47. Dr. H. Ungemach.
48. Dr. J. Drugman.

Front row.

49. Mr. T. H. Withers.
50. Mr. H. Heertz.
51. Mr. W. E. Swinton.
52. Mr. J. W. Walker.
53. Mr. E. D. Mountain.
54. Mr. G. Greenwood.
55. Mr. A. T. Hopwood.
56. Mr. S. I. Tomkeieff.
57. Prof. C. G. Cullis.
58. Prof. P. G. H. Boswell.
59. Mr. H. Buschor.
60. Dr. R. L. Parker.

Schultenite, a new mineral, from South-West Africa.

By L. J. Spencer, M.A., Sc.D., F.R.S.

With a chemical analysis by E. D. Mountain, M.A.

Mineral Department, British Museum (Natural History).

[Read November 2, 1926.]

Baron A. de Schulten,[1] a political refugee from Finland, worked during the latter part of his life in the chemical laboratories of the Sorbonne in Paris. There he prepared in a crystallized form a number of minerals and compounds analogous to them. These were determined crystallographically and compared in isomorphous series. For example, having obtained crystals of artificial monetite,[2] $CaHPO_4$, he then proceeded to prepare the corresponding compounds in which strontium, barium, or lead take the place of calcium, and arsenic the place of phosphorus.[3] In this series he determined the crystallographic constants and optical data for $CaHPO_4$, $SrHPO_4$, $BaHPO_4$, $PbHPO_4$, $SrHAsO_4$, and $PbHAsO_4$. Crystals of $CaHAsO_4$ were also obtained, but they were too small for measurement. Any of these compounds might be expected to occur in nature, but hitherto only monetite has been found as a mineral. His 'monétite arséniée de plomb' is the subject of the present note, and for it, as a mineral, the name schultenite is suggested. Baron Schulten presented to the British Museum collection in 1898 a small set of his artificial products, but unfortunately these include none of his monetite series.

[1] August Benjamin Friherre af Schultén (1856–1912); obituary notice, Min. Mag., 1913, vol. 16, p. 381.

[2] A. de Schulten, Reproduction artificielle de la monétite. Bull. Soc. Franç. Min., 1901, vol. 24, pp. 323–326.

—— Recherches sur le phosphate dicalcique. Reproduction artificielle de la brushite. Reproduction de la monétite par un nouveau procédé. Ibid., 1903, vol. 26, pp. 11–17.

[3] A. de Schulten, Reproduction artificielle de monétites de baryum, de plomb et de strontium et de monétites arséniées de plomb et de strontium. Ibid., 1904, vol. 27, pp. 109–123. (Monétite arséniée de plomb, p. 113.)

This compound, lead hydrogen orthoarsenate, $PbHAsO_4$, is the 'lead arsenate' of commerce, and was first prepared by J. J. Berzelius in 1819. It is used as an insecticide, especially in America in sprays for fruit-trees; and being practically insoluble in water it is no doubt responsible for the retention of arsenic in apples. H. Goguel [1] in 1895 obtained monoclinic crystals on which he determined some of the characters under the microscope. Later, in 1916, C. C. McDonnell and C. M. Smith,[2] in a detailed study of the several forms of lead arsenate, also gave some of the microscopic characters.

As yet only a single specimen representing the new mineral is known, but doubtless there are others in collections amongst the rich series of crystallized material that has come from the locality. This specimen [B.M. 1926, 205] was acquired in 1926 for the British Museum collection from Mr. Wilhelm Maucher of Munich, and was labelled 'Lanarkite: Tsumeb, Otavi, South-West Africa'. Although the mineral was incorrectly labelled lanarkite, there can be no doubt about the locality, for the specimen is very typical of the pseudomorphous crusts that have been found in abundance at Tsumeb. The lead chloro-arsenate (mimetite) is common at this locality.

The specimen shows a base of large (2 cm. across) crystals of yellowish anglesite which are altered on the surface and along cracks to bayldonite. Resting on the anglesite were tabular crystals probably of chessylite, and hexagonal prisms and rods no doubt representing mimetite; both of these are now completely changed to bayldonite. The bayldonite (a basic arsenate of lead and copper) is yellowish-green in the interior, and bluish-green and minutely crystalline on the surface. The new mineral rests on these pseudomorphs, and is somewhat intermixed with bayldonite.

The schultenite has the form of thin crystal plates which are perfectly transparent, clear, and colourless, and with a brilliant vitreous to almost adamantine lustre. The largest plates measure 1 cm. across with a thickness of 1 mm., and the smallest is about 1 mm. across. The material is brittle and easily crushed to a white powder; hardness $2\frac{1}{2}$.

The crystals are monoclinic (holohedral) with the elements:

$$a : b : c = 0{\cdot}8643 : 1 : 0{\cdot}7181, \ \beta = 84° \ 36',$$

[1] H. Goguel, Contribution à l'étude des arséniates et des antimoniates cristallisés préparés par voie humide. Mém. Soc. Sci. Bordeaux, 1895, vol. 1, pp. 83–157. (Orthoarséniate diplombique, p. 135.)

[2] C. C. McDonnell and C. M. Smith, Journ. Amer. Chem. Soc., 1916, vol. 38, p. 2030. A summary of the chemical literature is there given.

as calculated from the measured angles *cp*, *cl*, and *bl* given in the following table. A few other measured angles are also added for comparison with the calculated angles, sufficient to show that good results were obtained.

	Mean.	Limits.	No.	Calculated.
$cp = (001):(111)$ ...	45° 25′	45° 24′—45° 26′	9	*
$cl = (001):(130)$ ...	88 3	88 2—88 6	6	*
$bl = (010):(130)$ ...	21 10½	21 8—21 13	8	*
$bp = (010):(111)$ ...	62 12	62 3—62 23	16	62° 16′
$ce = (001):(011)$ ...	35 36	35 32—35 40	6	35 34
$st = (\bar{2}11):(\bar{2}21)$ ...	16 33	16 30—16 38	8	16 32

The complete list of sixteen forms and their angles is, however, given in a form of table (p. 153), which, it is believed, combines the advantages both of the arrangement in zones of interfacial angles (as adopted by Miller, Dana, Hintze, and Groth) and of the ϕ and ρ (longitude and latitude) angles employed in two-circle goniometry (as advocated by Goldschmidt). For monoclinic crystals the polar distances ρ are more conveniently taken from the fixed *b*-axis (the axis of symmetry), rather than from the arbitrary *c*-axis as done by Goldschmidt. The angle between any two faces lying in a zone containing one of the axial planes is at once given by the difference between two angles in the table. Such a table of angles can be quickly checked by placing a transparent stereographic net over the projection (fig. 3).

The crystals are all flattened parallel to the plane of symmetry *b* (010), parallel to which there is a good cleavage. The usual habit is rhomb-shaped (fig. 1), with much the appearance of crystals of gypsum. A small (1 mm.) crystal of this type, which was mounted on the goniometer, is completely developed on all sides. Less often the pyramid-faces *p* (111) are partly or sometimes completely cut out by the basal plane *c* (001) (fig. 2). The prominent prism is *l* (130), and *n* (140) is usually present as narrow faces, but *m* (110) is only rarely represented. Small clino-dome faces *e* (011) sometimes border the basal plane when the latter is present. Except for *p* (111), all the pyramid-faces are quite small. The faces *b* (010) are prominently striated parallel to their intersection with the prism-faces; and when *c* (001) is present they also bear less prominent striations parallel to and close to the edge *b*/*c*. The prism-faces are faintly striated vertically. The basal plane and the pyramids are perfectly smooth, and give single sharp images when not confused by sub-parallel growth of the crystals.

The determination of the optical constants presented some difficulty and unfortunately is not complete. The crystals are very thin and brittle, and the thicker and better crystals on the single specimen

could not be sacrificed for cutting oriented plates and prisms. Measurements of the extinction-angle on the plane of symmetry gave readings varying from 19° to 28° to the prism-edge in the acute angle β, the mean being 24°. Owing to the high refraction, the optic axes do not emerge into air through $b(010)$, and it was consequently at first thought that the optic axial plane was parallel to the plane of symmetry (as previously described for the artificial crystals). One optic axis is, however, visible through $p(111)$. A small fragment broken approximately perpendicular to the plane of symmetry and the cleavage, and giving straight extinction, showed a wide-angle biaxial figure of positive sign with the optic axial plane perpendicular to the plane of symmetry. The angle was estimated under the microscope with a micrometer scale as $2E_a = 135°$. By immersing a crystal in a trough of methylene iodide it was possible to observe the obtuse angle through $b(010)$, and on the Fuess axial angle apparatus this was measured as $2H_o = 146°\ 34'$ for sodium-light. Taking β as 1·9097 and for methylene iodide $n = 1{\cdot}742$, this gives:

$$2V_a = 58°\ 14' \text{ and } 2E_a = 136°\ 38' \text{ (Na)}.$$

The optical orientation of the crystals is: optic axial plane perpendicular to the plane of symmetry and lying in the obtuse angle β; $a(\mathrm{Bx}_o) = b$, $\beta : c = -24°$, $\gamma(\mathrm{Bx}_a) : c = +66°$; sign positive. These directions are plotted on the stereographic projection (fig. 3).

Refractive indices were determined by the prism method of minimum deviation through the natural prism given by the faces $l(130)$ $(1\bar{3}0)$, the refracting angle on the crystal employed being measured as 42° 22′. In such a prism the path of the light is symmetrical through the prism in the direction of the axis of symmetry; and the vibration-directions β and γ lie in the plane of symmetry, though not parallel and perpendicular to the refracting edge of the prism. The use of natural prisms of orthorhombic crystals in this connexion is well recognized, when the vibration-directions are parallel and perpendicular to the refracting edge; but for monoclinic crystals I have not been able to find any mention of this method in the text-books on crystallography and crystal-optics. With white light the schultenite prism gave two long and widely separated spectra, indicating high dispersion and strong birefringence. The crystal used was small and readings could not be obtained for lithium- and thallium-light. The values determined for sodium-light are:

$$\beta = 1{\cdot}9097 \text{ and } \gamma = 1{\cdot}9765 \text{ (Na)}.$$

Calculated from β, γ, and 2V, the value of α is 1·8903.

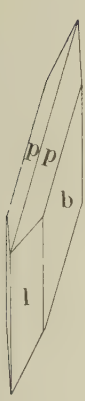


Fig. 1.

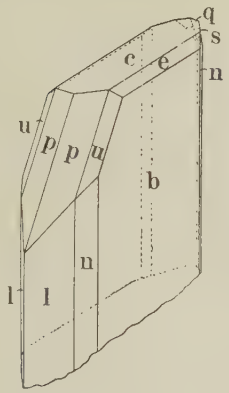


Fig. 2.

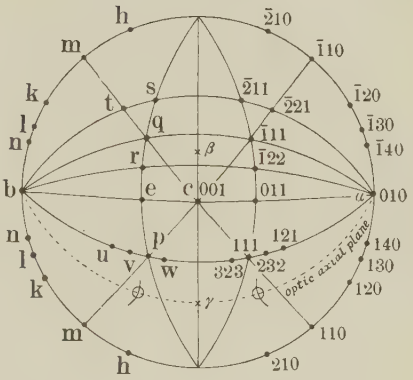


Fig. 3.

Crystals and Stereographic Projection of Schultenite.

Forms of Schultenite and the normal angles of each to the three axial planes.

Forms.			Angle to a (100).	Angle to b (010).	Angle to c (001).
b (010)	...	...	90° 0′	—	90° 0′
c (001)	...	...	84 36	90° 0′	—
h (210)	...	...	23 17	66 43	85 2
m (110)	...	...	40 43	49 17	86 0
k (120)	...	...	59 50	30 10	87 17
l (130)	...	...	68 50	21 10	88 3
n (140)	...	...	73 48	16 12	88 30
e (011)	...	...	85 36	54 26	35 34
[abs. (101)]	...	...	47 4	90 0	37 32
[abs. ($\bar{1}$02)]	...	...	107 55	90 0	23 19
[abs. ($\bar{1}$01)]	...	...	126 33	90 0	41 57
[abs. ($\bar{2}$01)]	...	...	147 37	90 0	63 1
w (323)	...	...	50 0	70 41	41 32
p (111)	...	...	52 55	61 16	45 25
v (232)	...	...	57 40	51 44	51 29
u (121)	...	...	62 0	43 34	56 52
r ($\bar{1}$22)	...	...	104 43	55 39	40 42
q ($\bar{1}$11)	...	...	121 3	60 1	49 54
s ($\bar{2}$11)	...	...	142 1	68 58	64 57
t ($\bar{2}$21)	...	...	132 1	52 26	68 56

The question of the crystallographic orientation must now be considered, since the one here adopted differs from that of Schulten for the artificial crystals. He gave the elements as $a : b : c = 0{\cdot}7212 : 1 : 0{\cdot}8704$, $\beta = 84° 23'$, and the forms recorded by him were g^1 (010), m (110),

e^1 (011), $b^{\frac{1}{2}}$ ($\bar{1}11$), and b^1 ($\bar{1}12$). Groth[1] adopts Schulten's orientation but letters the forms $b\,m\,q\,\omega\,i$ respectively. The difference amounts only to an interchange of the a and c axes; but to get the crystals into parallel position one must be rotated through $84\frac{1}{2}°$ and then turned over (180° about the new c-axis). The first and last indices of the forms must also be interchanged, but this affects only some of the forms. The following tabular comparison shows the differences, and at the same time shows that Schulten's measured angles (except those on which the calculations are based) are in closer agreement with my values than with his own calculated values.

Schulten.			Spencer.	
Angle.	Obs.	Calc.	Angle.	Calc.
(010) : (110)	54° 20′	*	(010) : (011)	54° 26′
(011) : (110)	63 46	*	(110) : (011)	64 4
(011) : ($\bar{1}$10)	71 15	*	($\bar{1}$10) : (011)	71 16
(010) : (011)	49 13	49° 6′	(010) : (110)	49 17
(010) : ($\bar{1}$11)	60 1	59 50	(010) : ($\bar{1}$11)	60 1
(010) : ($\bar{1}$12)	68 55	68 48	(010) : ($\bar{2}$11)	68 58
($\bar{1}$10) : ($\bar{1}$11)	35 17	35 20	(011) : ($\bar{1}$11)	35 27
($\bar{1}$12) : ($\bar{1}$11)	20 59	21 0	($\bar{2}$11) : ($\bar{1}$11)	20 58

On the natural crystals now described the zone chosen by Schulten for the prism-zone is frequently not developed (fig. 1), and when it is present [$b\,e\,c$] the prism-faces e are always small. Further, it is to be noted that the orientation here adopted is the same as the earlier one shown in the figure of H. Goguel (1895), whose paper is not mentioned by Schulten and was apparently unknown to him.

There remains the question of the optical orientation, which has been given incorrectly by previous authors for the artificial crystals. Goguel and Schulten both state that the optic axial plane is parallel to the plane of symmetry (this has been dealt with above). Goguel measured under the microscope the angle β as 83° 24′, and McDonnell and Smith (1916) give the corresponding value 84°; but both these authors give the extinction as being in the obtuse (not acute) angle β, their values to the prism-edge being $+21°$ to 22° (for n_p [i.e. β]) and $+29°$ respectively. Schulten gives the extinction-angle as 38° in the obtuse angle, which in the second orientation is equivalent to $32\frac{1}{2}°$ in the acute angle β. The statement of obtuse for acute angle is evidently a slip, and the variation 21° to $32\frac{1}{2}°$ (compare 19° to 28° above) may perhaps be due to dispersion.

[1] P. Groth, Chem. Kryst., 1908, vol. 2, p. 822.

It may be mentioned that the data recorded above for the natural crystals were all determined before the identity of the mineral with the artificial crystals was established by Mr. Mountain's analysis. The substance could not be identified from the crystallographic data alone, since a copy of Fedorov's 'Tables for Crystallo-chemical Analysis' was not available.

Pseudomorphs of anglesite after schultenite (?).—Another specimen [B.M. 1922, 338] from Tsumeb, acquired from Mr. W. Maucher in 1922, was labelled 'Anglesite pseudomorphous after a monoclinic mineral (lanarkite? or gypsum?)'. This shows lath-shaped tabular crystals up to $1\frac{1}{2}$ cm. long which are completely changed to an aggregate of small crystals of anglesite and stained with a later thin deposit of bayldonite. Most of the pseudo-crystals are merely hollow crusts, and, consisting of an aggregate of anglesite crystals, the form is not always distinct. Terminated crystals, however, show a form suggestive of fig. 1, and it is possible that these are really pseudomorphs of anglesite after schultenite.

Chemical Analysis of Schultenite.

The total weight of available material was 0·2981 gram. The crystal fragments were collected by Dr. Spencer and contained only a minute trace of bayldonite, the copper of which was not sufficient to determine. A specific gravity[1] determination by the pyknometer method gave a corrected value of 5·943.

The analysis was made on 0·2917 gram. The water was determined as loss of weight on heating to incipient fusion. The residual powder was dissolved in a small quantity of dilute nitric acid and the lead was precipitated as lead sulphate. Subsequently the arsenic was estimated as sulphide after prolonged reduction by hydrogen sulphide. The analysis gave the following results:

		Molec. ratios.		Calculated.
PbO	63·97 ...	0·287	2 ...	64·24
As_2O_5	32·18 ...	0·140	1 ...	33·17
H_2O	2·88 ...	0·160	1 ...	2·59
	99·03			100·00

This corresponds with the formula $2PbO . As_2O_5 . H_2O$ or $PbHAsO_4$.

[1] Specific gravity of the artificial crystals 6·076 (Schulten, 1904), 6·053 (McDonall and Smith, 1916).

Aramayoite, a new mineral, from Bolivia.

By L. J. Spencer, M.A., Sc.D., F.R.S.
With a chemical analysis by E. D. Mountain, M.A.
Mineral Department, British Museum (Natural History).

[Read November 2, 1926.]

BOLIVIAN minerals have been sent for examination and preservation in the British Museum collection at various times since 1894 by my old school-fellow Mr. Malcolm Roberts, A.R.S.M., now General Manager of the Compagnie Aramayo de Mines en Bolivie. Several of these have been described in the pages of this magazine (see vol. 14, p. 309). Although he has industriously collected Bolivian minerals for over thirty years he is only now rewarded by the discovery of a species new to science. The material which he has been good enough to entrust to me for description was recognized by him as being probably something new, and this was confirmed by a chemical analysis made by Mr. T. Burns McGhie in the assay office at Quechisla in Bolivia.

Following the wish of Mr. Roberts and also that of Don Carlos Victor Aramayo, the present Bolivian Minister in London, the new mineral is here named aramayoite, in honour of Señor Don Felix Avelino Aramayo, who until last year was the Managing Director of the Compagnie Aramayo de Mines en Bolivie, and formerly the Bolivian Minister in London and afterwards in Paris.

The mineral was found in 1925 in a wide lode carrying abundant silver-tin ore in the company's Animas mine at Chocaya,[1] province

[1] This locality is mentioned by A. A. Barba, 'Arte de los Metales', Madrid, 1639; English translation by the Earl of Sandwich, London, 1674, Book I, p. 115: 'And in the rich Mine of *Chocaya*, in the Province of the *Chichas*, in the richest Stones of that Oar they have found much Silver, like wyre woven together as aforesaid.'

Sud-Chichas, department Potosi, Bolivia. Only a single piece was found, one-half of which was sent by Mr. Roberts for the British Museum collection, the counterpart being kept in the collection at the mine offices in Bolivia. The specimen received shows an irregular pocket of aramayoite, about 8×6 cm., surrounded by a zone of pyrite, in massive tetrahedrite.

The aramayoite shows an irregular and confused aggregate of bright cleavage surfaces with striated areas at the edges, in much the same fashion as 'books' of mica. The colour is iron-black with brilliant metallic lustre on the perfect cleavage, and the mineral presents a certain resemblance to tetradymite and franckeite.[1] The cleavage surfaces are about a centimetre across, and the 'books' are $\frac{1}{4}-\frac{1}{2}$ cm. measured in a direction perpendicular to the cleavage. Thin cleavage flakes are pliable but not elastic. They break up with square or rectangular outlines, and on the surface they are marked by striae and steps in two directions at right angles. Occasionally there are also sharp lines of fracture at 45° (as measured under the microscope) to the first set. The crystals therefore appear to be tetragonal with perfect basal cleavage $c(001)$ and good cleavages at the edges in the zones [001, 100] and [001, 110]. The mineral is somewhat sectile. When powdered in an agate mortar it breaks up into short fibres which have a tendency to clog together. The streak is black, and the hardness $2\frac{1}{2}$. The cleavage flakes are quite opaque.

Numerous fragments were placed on the goniometer, but unfortunately no satisfactory measurements could be obtained. The fibrous cleavage at the edges of the plates, which at first sight appeared to be parallel to the tetragonal prism $a(100)$ gave scattered and banded reflections. The most prominent reflections were at 73° to 80° from $c(001)$, with a mean of about 77°. No marked difference could be noticed in the two zones at right angles. The cleavages that give rise to the square outlines are therefore pyramidal. Various other readings were, however, obtained; the more frequent being about 53° and 40°, suggesting other pyramidal cleavages, while an occasional poor reflection at about 90° suggested a prismatic cleavage $a(100)$. The rarer zones at 45° to the first set gave no consistent results.

[1] Franckeite (of A. W. Stelzner, Neues Jahrb. Min., 1893, vol. ii, p. 114) was named after the brothers Carl and Ernst Francke, with whom Mr. Aramayo was formerly associated in Aramayo Francke Mines Limited, and curiously came from this same locality.

On one part of the specimen the aramayoite shows a drusy crystalline surface with a cellular or skeletal growth, and gives simultaneous reflections of light from numerous isolated spots over considerable areas. The small square basal planes, which fall approximately together to give larger areas, are bounded at the edges by pyramidal facets. These are coarsely striated parallel to their intersection with the basal plane. Fragments of this aggregate when placed on the goniometer gave scattered images from the basal planes and banded images from the pyramidal facets. The more prominent reflections gave angles of about 55° from $c\,(001)$; others were at about 77° and 40°.

These measurements are not reliable, and they are admittedly biased in the endeavour to arrive at some consistent results. Taking the more prominent pyramidal cleavage as $f\,(301)$ and at 77° from $c\,(001)$, this gives the calculated angle $c\,(001) : e\,(101) = 55° 18'$, and the axial ratio $a : c = 1 : 1{\cdot}44$. This agrees with the best angle from pyramidal facets on the drusy surfaces, but not so well with the angle 53° from the cleavages. The angle of about 40° from both facets and cleavages suggests the calculated angle $c\,(001) : y\,(305) = 40° 54'$. The few poor measurements from facets and cleavages in the zone [001, 110] are not consistent with these values.

The bulk of the specimen consists of massive tetrahedrite. Similar material from the lode assays up to twelve per cent. of silver. Mr. Roberts suggests that stannite is also perhaps present, but this is not distinguishable from the massive tetrahedrite. The pyrite is granular. Along a crevice it is present as small crystals with the forms $o\,(111)$ and $e\,(210)$ equally developed, giving a form bounded by twenty triangular faces. Small colourless to white crystals of quartz are present in small cavities in the tetrahedrite.

A curious change came over the aramayoite after it had been in the museum for about two months. The specimen had been kept under observation in a glazed case (facing the morning sun) in the work-room. It remained bright and shining until one morning, when it was noticed that the aramayoite on the side of the specimen towards the glass was white and dusty. This white coating was wiped off, but appeared again the next day. The specimen has since been kept in the dark, and there have been no further signs of misbehaviour. The white film was very easily wiped off, and it had quite the appearance of the well-known deposit from ammonium chloride vapour. It was the merest film, and was not examined chemically. After the film had been wiped off the underlying aramayoite, though still bright, was not quite so brilliant,

and it showed a slight iridescent tarnish. On the other side of the specimen the aramayoite was not affected, and this still shows its original brilliant lustre.

No explanation of this curious phenomenon can be given. Cleavage flakes of the mineral exposed to direct sunlight in a south window for four weeks showed not the slightest change. The only liquid in the case together with the specimen was methylene iodide. The pyrite on the specimen shows no sign of decomposition, although the specimen has a slight 'acid' or 'metallic' smell. It may sometimes be noticed, especially in damp weather, that a museum case exposed to direct sunlight and then coming into shadow will show a rapid condensation of moisture inside the glass. Cleavage flakes of aramayoite immersed in water or floating on the surface, or resting on wet blotting-paper, when exposed to direct sunlight showed no change. Others were steamed and boiled in water or dilute sulphuric acid, and in strong hydrochloric acid, but they still persisted in the display of their brilliant metallic lustre. Methylene iodide had no action. In the vapour of strong hydrochloric acid or nitric acid at the ordinary temperature the cleavage flakes became tarnished after some days; and in the nitric acid vapour a white crust was formed on portions of the surface. The powdered mineral is slowly decomposed by hot strong nitric acid with separation of a white precipitate, but hot strong hydrochloric acid has no action.

The crystallographic determinations given above (which are left as first written) are evidently incomplete and unsatisfactory. The excellent cleavage plates suggested that an X-ray Laue photograph might give some clue to the symmetry of the crystals; and, through the kindness of Sir William H. Bragg, an X-ray examination of the new mineral has been made by Miss Yardley in the Davy-Faraday Laboratory of the Royal Institution. Her results are of such importance that they are presented below in a separate paper. They afford a striking example of how X-ray methods may come to the aid of descriptive mineralogy when the usual crystallographic methods fail. Miss Yardley finds the absence of planes and axes of symmetry and has been able to completely determine the crystallographic constants of the triclinic crystal. Her results, based on internal structure, point to a pseudo-tetragonal type; and this is confirmed by the external characters, as indicated by the cleavages. The main cleavage plane is the basal plane of the pseudo-tetragonal cell.

When preparing cleavage flakes for the X-ray examination, Miss Yardley made an interesting observation which is best recorded in this place. The

main (001) cleavage surfaces sometimes showed minute (0·01—0·1 mm.) square pits with steep sloping sides, and very like etch-figures in appearance.[1] These were evidently formed by the ripping out of material along the 'pyramidal' cleavages. The pits are occasionally octagonal in outline, due, no doubt, to the second set of 'pyramidal' cleavages. Sometimes the pits completely penetrate the cleavage flake, leaving square windows; whilst at other times an extremely thin layer of the material is left at the bottom of the pit. When these pits are examined under a high magnification in sunlight or in a brilliant artificial light they sometimes show a deep blood-red colour by transmitted light. The same colour was also sometimes to be seen on the frayed edges of the cleavage fragments. The statement made above that the mineral is opaque therefore requires qualification. Fragments were again crushed in oil on a microscope slide, but under these conditions only occasionally could the red colour be seen by transmitted light. Several thin cleavage flakes mounted in Canada-balsam were rubbed down as far as possible, but they still remained quite opaque. The streak of the mineral was again examined, and it was found to be black without any indication of red.

Miss Yardley's preparations were further examined between crossed nicols, when the blood-red colour showed up much more vividly. The extinction is uniform and at about 4° to the traces of the prominent 'pyramidal' cleavage. An interference-figure in convergent polarized light could not be obtained. This observation in parallel polarized light proves at once that the mineral is not tetragonal; but from a consideration of the cleavages it may be described as pseudo-tetragonal.

The new mineral is shown by chemical analysis to be a sulphantimonite of silver with a large part of the antimony replaced by bismuth, the formula being $Ag_2S.(Sb,Bi)_2S_3$ or $Ag(Sb,Bi)S_2$. This suggests a bismuth-bearing variety of miargyrite ($AgSbS_2$). But crystallographically it is quite distinct from miargyrite; the latter being monoclinic with no prominent cleavage, a cherry-red streak, and blood-red and translucent in thin splinters. It also differs from matildite ($AgBiS_2$), which is described as forming striated needles, or massive, without cleavage. The characters given for plenargyrite ($AgBiS_2$) do not appear sufficient to distinguish it from matildite. Being pseudo-tetragonal and with perfect basal cleavage and good pyramidal cleav-

[1] Similar figures on fluorite and some other minerals have been described (in Japanese) and figured by M. Kuhara, Journ. Geol. Soc. Tokyo, 1919, vol. 26, pp. 208–214, 335–341, pls. VIII–X, XII–XIV, and called 'tear-figures'.

ages, aramayoite is quite distinct crystallographically from any other sulpho-salt, and it creates a new subdivision in the $RS.(As,Sb,Bi)_2S_3$ group.

Chemical Composition of Aramayoite. (By E. D. Mountain.)

The preliminary analysis made by Mr. T. B. McGhie gave the following results:

			Atomic ratios.	FeS_2.	$Cu_3Sb_2S_7$.	SiO_2.	Remainder.	
S	...	25·17	0·785	28	14	—	743	
Sb	...	31·00	0·259	—	4	—	255	303
Bi	...	10·00	0·048	—	—	—	48	
Ag	...	32·12	0·298	—	—	—	298	
Cu	...	1·00	0·016	—	16	—	—	
Sn	...	trace	—	—	—	—	—	
Pb	...	nil	—	—	—	—	—	
Fe	...	0·80	0·014	14	—	—	—	
SiO_2	...	0·40	0·008	—	—	8	—	
		100·49						
Weight percentages		...	—	1·71	1·93	0·40	—	

Assuming that the iron is present as pyrite, the copper as tetrahedrite, and the silica as quartz, we obtain for the remainder the molecular ratios $Ag : Sb + Bi : S = 2 : 2 : 5$. The analyst himself, however, assumed the copper to be present in the form of chalcopyrite, but otherwise obtained substantially the same result.

As this analysis showed probable impurities of 4·04 % and an excess of sulphur over the normal ratio to the bases, silver, antimony, and bismuth, it was considered advisable to repeat the analysis on as pure material as could be collected. For this purpose Dr. Spencer picked out about two grams of very pure cleavage flakes.

Two independent determinations of the specific gravity by the pyknometer method on 0·9047 gram and 0·9962 gram respectively gave identical results of 5·602 after correction by the Hutchinson graph. Preliminary tests showed the absence of tin and only a trace of iron. When heated in a bulb-tube, the mineral decrepitates and melts at a low temperature, with partial volatilization, to a black mass which cools to a bright metallic bead.

A quantitative analysis was carried out on 0·7613 gram of powdered material. A separation was first made by heating to a dull-red heat in a current of chlorine, thus driving off the sulphur, antimony, iron, and bismuth in that order. The sulphur was determined in a separate

portion weighing 0·5973 gram by the fusion method. The analysis gave the following results:

		Atomic ratios.	$Cu_8Sb_2S_7$.	Remainder.	Calculated.
S ...	20·87	0·651	7	644	20·66
Sb ...	29·95	0·250	2	248 } 314	30·55
Bi ...	13·75	0·066	—	066 }	14·02
Ag ...	34·74	0·322	—	322	34·77
Cu ...	0·53	0·008	8	—	—
Fe ...	trace	—	—	—	—
	99·84				100·00

These results give $Ag : Sb + Bi : S = 1 : 1 : 2$, corresponding with the formula $Ag(Sb,Bi)S_2$ or $Ag_2S \cdot (Sb,Bi)_2S_3$.

X-ray examination of aramayoite.

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[Read November 2, 1926; communicated by Sir William H. Bragg, F.R.S.]

AN attempt was made to determine the true symmetry of the cleavage flakes of aramayoite by means of the Laue photographic method. Since X-ray diffraction takes place within the crystal, the lack of well-developed faces other than main cleavage faces was no disadvantage. One feature, however, which did prove a difficulty, was the pliability of thin cleavage flakes referred to by Dr. Spencer.[1] It was essential that the whole of the main cleavage face upon which the X-ray beam was incident should be strictly perpendicular to that beam. In order to ensure this, only those flakes were used which gave a single optical reflection, and two distinct methods of setting were resorted to. In the first case the slit (circular aperture) was used vertically; the flat end of the slit system was ground truly perpendicular to the slit itself and was thus horizontal. The crystal flake was laid on a glass coverslip so as to cover the upper end of the slit and it was then assumed that the cleavage face should be perpendicular to the slit and therefore to the X-ray beam (fig. 1 *b*). The Laue photograph obtained on a plate supported parallel to the flat end of the slit system showed no symmetry whatever. A second method of setting was then employed; a fine pencil of light was sent down the slit (used horizontally) and made to impinge on a crystal flake at about 6 mm. from the opposite end. The flake was adjusted until the reflected beam returned exactly along the path of the incident beam (fig. 1 *a*). In that position the flake was perpendicular to the beam of light and therefore to the X-ray beam which was afterwards substituted. The photographs obtained from this setting with various specimens were entirely similar to those previously obtained by means of the first method. By tilting the flake a photograph showing pseudo-tetragonal symmetry could be obtained, but a flake properly set with the main cleavage face normal to the beam gave a completely asymmetric picture (fig. 2). The inference was, therefore,

[1] L. J. Spencer, Aramayoite, a new mineral, from Bolivia. This vol., p. 156.

that perpendicular to the main cleavage plane there were no elements of symmetry whatever. A Laue photograph taken in that direction could, of course, give no information as to the existence of a symmetry plane parallel to the main cleavage itself.

In view of the fact that so far the examination had revealed none of the symmetry suspected by Dr. Spencer, the investigation was extended still farther. A quantity of the mineral was ground as finely as possible in an agate mortar, and a photograph was taken using the

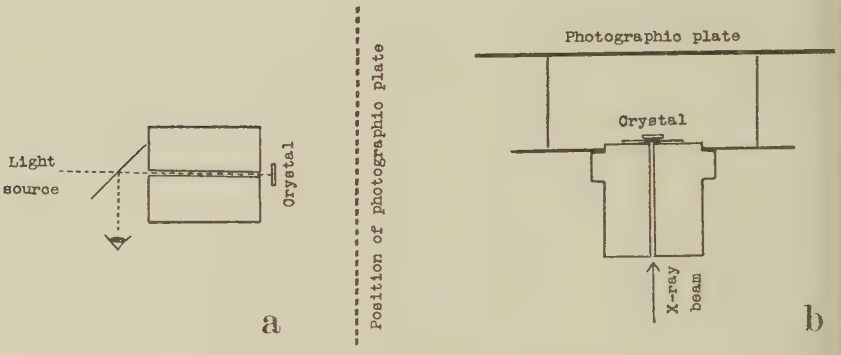

Fig. 1. Arrangement of apparatus for X-ray Laue photographs.
(*a*) Slit horizontal; (*b*) slit vertical.

resulting powder. In order to avoid orientation of the powder, the latter was mixed with a little water and a strip of paper was dipped into the mixture. When the water had dried off, the paper was covered with a fine layer of the powder and the subsequent photographs showed clear but broad lines corresponding to the following mean spacings (Cu radiation).

Spacing.	Intensity.	Spacing.	Intensity.
3·89	very weak	2·06	mod. weak
3·43	moderate	1·94	mod. weak
3·20	moderate	1·76	weak
2·83	strong	1·71	weak

These lines are not consistent with a tetragonal cell of the relative dimensions $a : c = 1 : 1{\cdot}44$, nor do they, in fact, correspond very closely with a tetragonal cell of any axial ratio whatever.[1]

[1] Cf. A. W. Hull and W. P. Davey, Physical Rev., 1921, vol. 17, p. 549.

Finally, the mineral was examined on the Bragg ionization spectrometer, and the spacings of and angles between a considerable number of planes were measured. These results showed beyond doubt that the mineral is triclinic and explained some of the inconsistencies mentioned by Dr. Spencer. The reflections from the main cleavage face were comparatively small, the first order observed being less than one-third as intense as those from some other planes in the crystal. This is unusual,

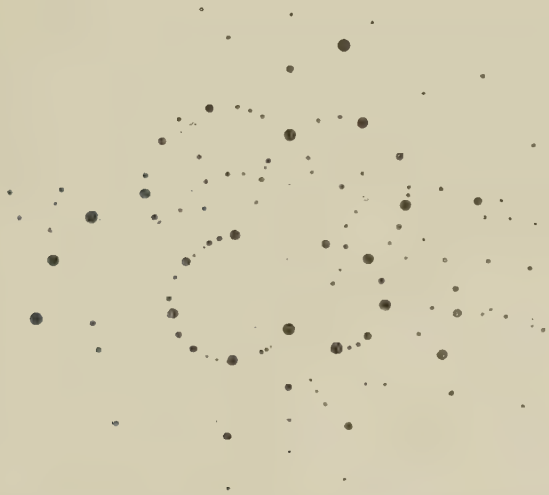

FIG. 2. Laue diagram of aramayoite. X-ray beam perpendicular to (001); (110) vertical.

since in such crystals as calcite and mica the main cleavage face gives quite the most intense reflection of all. Reflections from planes in four zones were measured, each of the zone-axes lying in the cleavage plane (001). Thus although accurate measurements could be obtained of the angles between the basal plane and the various pyramid and prism faces, no direct measurements of angles between side planes were made. Knowing the spacings of these side planes, however, the angles between them could be calculated fairly accurately from the formula

$$\left(\frac{1}{d_{hk0}}\right)^2 \quad \left(\frac{h}{d_{100}}\right)^2 + \left(\frac{k}{d_{010}}\right)^2 - \frac{2hk \cdot \cos(100:010)}{d_{100} \cdot d_{010}}.$$

The experimental results lead to a minimum unit cell of the dimensions

$a = 5{\cdot}672$ Å.U. $\quad \alpha = 86° 55'$
$b = 5{\cdot}688 \quad \beta = 90\ 53$
$c = 5{\cdot}623 \quad \gamma = 93\ 18$

Hence $a : b : c = 0{\cdot}9972 : 1 : 0{\cdot}9886$.

This cell would contain two molecules of the constitution $Ag(Sb,Bi)S_2$, or one molecule of $Ag_2S\,.\,(Sb,Bi)_2S_3$, the proportion of Sb to Bi being taken as that given by Mr. Mountain's analysis. No reflections were observed that would indicate a larger cell than the above, and the observed reflections eliminate all smaller cells. The experimental results are tabulated below. No fifth-order reflections were observed, but there was one sixth-order reflection (intensity 5) from the plane (001).

			Angle to	Relative intensities of orders			
(*hkl*).	*d* (calc.).	*d* (obs.).	(001) (obs.).	I.	II.	III.	IV.
(100)	5·662	5·64	91° 4′	—	170	—	37
(010)	5·670	5·67	86 52	—	180	—	34
(001)	5·614	5·61	0	—	52	—	23
(110)	3·899	3·89	88 38	—	92	—	3
($\bar{1}$10)	4·127	4·13	86 36	4	134	—	14
(101)	3·962	3·94	44 4	17	100	7	9
(10$\bar{1}$)	4·013	4·04	44 59	—	95	—	8
(201)	2·516	2·51	62 16	—	22	—	—
(20$\bar{1}$)	2·541	2·55	64 9	—	20	—	—
(102)	2·503	2·50	25 56	—	16	—	—
(10$\bar{2}$)	2·526	2·54	26 34	—	15	—	—
(301)	1·783	1·78	70 24	16	—	—	—
(30$\bar{1}$)	1·795	$1{\cdot}79_5$	72 19	9	—	—	—
(011)	4·102	4·09	46 16	—	110	—	—
(01$\bar{1}$)	3·888	3·88	43 4	?	115	—	4
(012)	2·572	2·57	26 52	—	15	—	—
(01$\bar{2}$)	2·465	2·48	25 42	—	14	—	—
(021)	2·588	2·58	65 43	—	27	—	—
(02$\bar{1}$)	2·473	2·50	60 44½	—	21	—	—
(111)	3·246	3·24	56 10	100	56	5	—
(11$\bar{1}$)	3·164	$3{\cdot}16_5$	54 20	108	54	7	—
(113)	1·707	$1{\cdot}70_5$	25 58	25	—	—	—
(11$\bar{3}$)	1·669	$1{\cdot}67_5$	25 26	25	—	—	—
(331)	1·274	1·27	78 18	17	—	—	—
(33$\bar{1}$)	1·258	1·26	75 44	18	—	—	—
($\bar{1}$11)	3·404	$3{\cdot}42_5$	55 41	165	77	22	5
($\bar{1}\bar{1}$1)	3·252	3·23	51 28	124	65	15	—
($\bar{1}$13)	1·736	1·73	24 49	30	—	—	—
($\bar{2}$2$\bar{1}$)	1·911	1·91	66 51	—	12	—	—
($\bar{3}$1$\bar{3}$)	1·351	$1{\cdot}35_5$	79 7	37	—	—	—
($\bar{3}$3$\bar{1}$)	1·322	1·32	73 8	33	—	—	—

The planes (110), ($\bar{1}$10), and (001) in the above cell correspond to Dr. Spencer's three axial planes ((100), (010), and (001) respectively), the difference in orientation being given by a rotation of approximately 45° about the *c*-axis. The small odd-order reflections observed from the (101) and other 'mixed indices' planes show, however, that his cell, which is nearly tetragonal in shape, is not a possible minimum cell. The prominent cleavages and pyramidal facets observed at angles

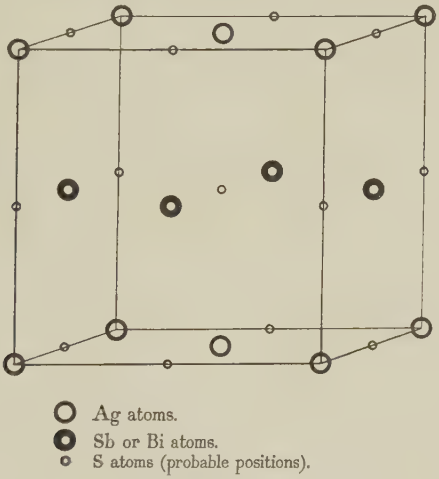

FIG. 3. Lattice of aramayoite, $Ag(Sb,Bi)S_2$.

varying from 73° to 80° from the basal plane would correspond to the planes ($\bar{3}3\bar{1}$), (33$\bar{1}$), (331), and ($\bar{3}$31). The angles made by these planes with (001), when measured on the X-ray spectrometer, were found to be 73° 8′, 75° 44′, 78° 18′, 79° 7′ respectively. The goniometrical results, therefore, which appeared to be inconsistent on the hypothesis of a tetragonal cell, become perfectly consistent when considered in the light of the X-ray analysis. Again it may be noticed, however, that the X-ray reflections from these planes are by no means among the most intense that were observed. The occasional optical reflections at about 55° and 90° are easily explicable on the basis of the triclinic cell, and the reflections at about 40°, while not corresponding to any plane from which X-ray reflections were actually observed, may quite possibly be due to the (33$\bar{5}$) or the ($\bar{2}2\bar{3}$) or some more complex plane. The powder photograph lines are completely accounted for by reference to the table of results, though many of the weaker reflections could not

be seen on the photograph. The majority of the lines are due to more than one reflection and are consequently broad.

The intensities given in the table are extremely interesting. The only planes for which comparatively large first-orders were found are those all of whose indices are odd. In nearly all other cases the odd orders were either absent (that is, too weak for observation) or very small compared with the even orders. This shows that the cell is very nearly face-centred, and since there are only four heavy atoms in the cell, those four must lie at or very near the positions (000) $(0\frac{1}{2}\frac{1}{2})$ $(\frac{1}{2}0\frac{1}{2})$ $(\frac{1}{2}\frac{1}{2}0)$. The similarities between the intensities of reflection from, and the spacings of, the planes (100) and (010) point to an arrangement in which Sb(Bi) atoms lie at (000) $(\frac{1}{2}\frac{1}{2}0)$ and Ag atoms at $(0\frac{1}{2}\frac{1}{2})$ $(\frac{1}{2}0\frac{1}{2})$. The main cleavage planes, (001), would then consist of alternate layers of Sb and Ag atoms, whereas in the (100) and (010) planes the Sb and Ag are coplanar. The positions of the S atoms are not so clearly indicated, but various possibilities may be eliminated by a consideration of the relative intensities of the different order reflections. Thus the diamond arrangement may be dismissed because it would lead to a (400) reflection strong compared with the (200), and a (222) reflection weak compared with the (111). The reverse is actually the case, when allowance is made for the ' normal ' falling-off of intensities. The NaCl arrangement (Sb and Ag replacing 2Na, and S replacing Cl) is a more probable one, but is not altogether satisfactory. In that case the S atoms would be located at the points $(\frac{1}{2}00)$ $(0\frac{1}{2}0)$ $(00\frac{1}{2})$ $(\frac{1}{2}\frac{1}{2}\frac{1}{2})$ (fig. 3). It is doubtful whether the results obtained from a more detailed analysis of the intensity data would at present justify the time and labour involved.

The structure of baddeleyite and of prepared zirconia.

By Kathleen Yardley, M.Sc.

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[Read November 2, 1926; communicated by Sir William H. Bragg, F.R.S.]

THE crystal used in the first part of this investigation, an untwinned specimen from Ceylon in the British Museum collection, was measured goniometrically and described in detail by Dr. G. F. Herbert Smith,[1] who gave as its crystallographic constants:

Density (ρ) 5·82 (grs./c.c.). Monoclinic prismatic,

$$a : b : c = 0{\cdot}9905 : 1 : 0{\cdot}5110,\ \beta = 80^\circ\ 32'.$$

Owing to the comparatively large size of the crystal and its high absorptive power it was unsuited either to the 'rotating crystal' or Laue photographic methods of X-ray examination. Reflections from the faces were observed on the Bragg ionization spectrometer and spacings measured with an accuracy of about 2 per cent. It soon became apparent that the c-axis should be doubled, the true axial ratio being

$$a : b : c = 0{\cdot}9905 : 1 : 1{\cdot}0220,\ \beta = 80^\circ\ 32',$$

this double length of the c-axis being as taken by Sir L. Fletcher[2] in the original description of baddeleyite. Thus the faces recorded by Dr. Smith as (221) are really the (111) and so on. The true unit cell contains *four* molecules of ZrO_2 ($M = 122{\cdot}6$). No indications were found of any larger cell.

The density of this crystal, 5·82, is higher than that of pure zirconia, which is only 5·73 (G. Hevesy, 1925) and therefore some heavier impurity, possibly HfO_2, must be present. One result of this is that the spacings calculated from the formula $a.\ b.\ c.\ \sin\beta.\ \rho = n.\ M.$ 1·65 are all consistently smaller, on an average by about 2 per cent., than the

[1] G. S. Blake and G. F. H. Smith, Min. Mag., 1907, vol. 14, p. 378, fig. 2.

[2] L. Fletcher, Min. Mag., 1893, vol. 10, p. 148.

observed spacings, owing to the fact that the presence of the impurity should have been allowed for in M, the molecular weight. A better agreement was obtained by taking $M = 128$ as a hypothetical molecular weight for (ZrO_2 + impurity). In the following table the observed and calculated values are compared:

Plane.		Spacing.			Comparative Intensities.					
Old indices.	New indices.	Calc. from older data.	Calc. from new ($M = 128$).	Obs.	I.	II.	III.	IV.	V.	VI.
(100)	(100)	5·06	5·14	5·10	1	20	4	10	5	2
(010)	(010)	5·18	5·26	$2{\cdot}61_5$*	0	1	0	–	–	–
(001)	(001)	2·61	5·30	2·65*	0	1	0	–	–	–
(021)	(011)	1·84	3·73	3·75	1	24	–	–	–	–
(201)	(101)	1·68	3·42	1·71*	0	4	0	1	0	–
(110)	(110)	3·62	3·67	3·62	1	16	2	–	–	–
(210)	(210)	$2{\cdot}27_5$	$2{\cdot}30_5$	2·30	1?	8	–	–	–	–
(221)	(111)	1·41	$2{\cdot}87_5$	2·92	1	–	–	–	–	–
(22$\bar{1}$)	(11$\bar{1}$)	1·58	3·20	3·26	1	–	–	–	–	–

The calculated dimensions of the cell are:

$$a = 5{\cdot}21,\ b = 5{\cdot}26,\ c = 5{\cdot}37_5 \text{ Å.U.},\ \beta = 80° 32'.$$

The intensities given in the above table are stated in arbitrary units for each plane. In general, reflections could only be observed from planes actually present as faces on the crystal (a Rh anticathode being used), and the intensity of reflection depended to a large extent on the size and perfection of the face. This was proved by comparing reflections from the (100) and ($\bar{1}$00) faces, and also from the (110) and (1$\bar{1}$0) faces, which are very unequally developed on the specimen. The larger of each of these pairs of faces gave good sharp reflections, whereas the reflections from badly developed planes such as the (001) were small and ill defined. No weight, therefore, could be attached to any comparison of intensities of reflection from different planes, though for any one plane a comparison of intensities of different orders is legitimate and useful. In the case of planes (010), (001), and (101) (marked in the table by an asterisk) a careful search revealed no trace of odd-order reflections. The two last-named belong to the set of planes $\{h0l\}$ where l is odd; the odd orders of the (100) plane, on the contrary, though weaker than the even orders were most decidedly present. Many attempts were made to find other reflections in the [010] zone, but this could not be done with the crystal used, and other untwinned samples of the material are very rare.

The original crystals of baddeleyite ('brazilite') from Jacupiranga,

Brazil, described in 1892 by Dr. E. Hussak,[1] which are preserved in the British Museum collection, were also examined. These are much smaller (all less than $\frac{1}{2}$ mm.^{3}) and were found to be twins on the planes (100), (110), and (101). Rotation photographs were taken with one of the simplest twins, using a Mo anticathode, but the resulting pictures even after exposures of upwards of 16 hours showed only a few of the more intense reflections and gave little additional information. No odd-order reflections from planes $\{h0l\}$ where l is odd could be observed, but the photograph obtained by rotation about the b-axis showed faint spots corresponding to planes (204) or (402) and (20$\bar{4}$) or (40$\bar{2}$).

Finally, the nodular fibrous zirconia from Serra de Caldas, Brazil, was examined. This was first described in 1903 by E. Hussak and J. Reitinger,[2] and was considered by them to represent perhaps a new modification of zirconia distinct from baddeleyite. They gave the density of this material as 5·538, and ZrO_2 97·19 per cent. A fragment of similar material from a specimen in the British Museum collection was crushed in an agate mortar and a powder photograph taken using Cu ($K\alpha$) radiation. A calibration photograph was obtained by mixing the powder with calcite powder. The lines obtained on the photograph proved the identity of this material with baddeleyite, and agreed better with the data given by Dr. Smith for the large single crystal than with those of Hussak (1895). The data given by Dr. Smith were therefore used in the calculations of sin θ (column 2 in the following table). They confirm the cell chosen and the number of molecules per cell, and lead to a length of axis $b = 5{\cdot}188$ Å.U. as against 5·209 calculated from the density 5·73. The calculated density of this specimen is therefore slightly higher than for pure zirconia.

(hkl).	sin θ calc.	sin θ obs.	d.	Intensity.
(001)	0·1470			
(010)	0·1482			
*(100)	0·1517			
(10$\bar{1}$)	0·1931			
*(011)	0·2087	0·2096	3·667	Weak.
*(110)	0·2120			
(101)	0·2279			
*(11$\bar{1}$)	0·2434	0·2433	3·159	Very strong.

[1] E. Hussak, Neues Jahrb. Min., 1892, vol. ii, p. 141 ; Tschermaks Min. Petr. Mitt., 1895, vol. 14, p. 406.

[2] E. Hussak and J. Reitinger, Zeits. Kryst. Min., 1903, vol. 37, p. 572. 'Brazilite' and some other names have been applied to this material (Min. Mag., 1919, vol. 18, p. 375).

(*khl*).	sin θ calc.	sin θ obs.	*d*.	Intensity.
*(111)	0·2719	0·2720	2·826	Strong.
*(002)	0·2940	0·2944	2·611	Mod. strong.
*(020)	0·2964			
*(200)	0·3019	0·3033	2·535	Mod. weak.
(10$\bar{2}$)	0·3078			
(20$\bar{1}$)	0·3132			
(012)	0·3292	0·3301	2·329	Weak.
(021)	0·3308			
(120)	0·3329			
(210)	0·3363			
(11$\bar{2}$)	0·3417			
(21$\bar{1}$)	0·3464	0·3493	2·201	Moderate.
(102)	0·3523			
(12$\bar{1}$)	0·3537			
(201)	0·3570			
(121)	0·3739			
(112)	0·3822			
(20$\bar{2}$)	0·3861	0·3839	2·003	Mod. weak (broad).
(211)	0·3865			
*(022)	0·4175	0·4166	1·845	Mod. strong.
(21$\bar{2}$)	0·4233			
*(220)	0·4241	0·4255	1·807	Mod. strong.
(12$\bar{2}$)	0·4273			
(22$\bar{1}$)	0·4312			
(003)	0·4410			
(10$\bar{3}$)	0·4421			
(030)	0·4445			
(30$\bar{1}$)	0·4547			
*(300)	0·4550	0·4549	1·690	Moderate.
*(202)	0·4558			
(122)	0·4604			
(221)	0·4639			
(013)	0·4652	0·4648	1·654	Moderate.
(11$\bar{3}$)	0·4663			
(031)	0·4682			
(130)	0·4697			
(31$\bar{1}$)	0·4782	0·4783	1·607	Very weak.
(310)	0·4785			
(212)	0·4793			
(13$\bar{1}$)	0·4846			
(22$\bar{2}$)	0·4868			
(103)	0·4894			
(20$\bar{3}$)	0·4917			
(30$\bar{2}$)	0·4995	0·4999	1·538	Mod. weak.
(131)	0·4996			
(301)	0·5006			
(113)	0·5113	0·5100	1·507	Weak.
(213)	0·5134			
(31$\bar{2}$)	0·5210			

(*hkl*).	sin θ calc.	sin θ obs.	*d*.	Intensity.
(311)	0·5221	0·5222	1·472	Weak.
(023)	0·5313	0·5314	1·447	Very weak.
(12$\bar{3}$)	0·5323			
(032)	0·5330			
(230)	0·5373			
(13$\bar{2}$)	0·5407			
(32$\bar{1}$)	0·5427			
(320)	0·5430			
(23$\bar{1}$)	0·5437			
(222)	0·5437			

It is difficult to be certain as to the indices of the planes giving some of the observed lines. The planes observed on the spectrometer are marked by an asterisk, though it must be remembered, of course, that, owing to the varying amounts of impurity present, the spacings from different samples of baddeleyite cannot be expected to agree very closely. The line for which sin $\theta = 0{\cdot}4255$ may be due to any or all of the three planes (21$\bar{2}$) (220) (12$\bar{2}$), but the large spectrometer reflection observed from (220) renders it highly probable that the latter is the main contributing plane. Similarly, the line 0·4549 is probably due to the planes (300) and (202), although the possibility of a contribution from (30$\bar{1}$) cannot be definitely eliminated. However, on the whole it may be stated that the powder lines are in substantial agreement with the space-group C_{2h}^5, for which odd-order reflections from planes $\{h0l\}$ where l is odd and from (010) would be absent.[1]

It is significant that, contrary to expectation, the powder photographs from two separate specimens of artificially prepared zirconia were almost identical with those from the natural oxide. A sample from the firm of Kahlbaum gave the value $b = 5{\cdot}193$ Å.U., again showing a slightly high value of the density. The photographs, with the exception of one line, fitted the monoclinic lattice very well, and could not be made to agree with a tetragonal lattice of any axial ratio whatever.

The data given by A. E. Nordenskiöld [2] describing artificially prepared crystals of zirconia as tetragonal, with an axial ratio $a : c = 1 : 1{\cdot}0061$, are certainly not applicable to either of the samples used in the present

[1] P. Niggli, Geometrische Kristallographie des Diskontinuums, Leipzig, 1919; also W. T. Astbury and K. Yardley, Phil. Trans. Roy. Soc. London, Ser. A, 1924, vol. 224, p. 221.

[2] A. E. Nordenskiöld, Öfvers. K. Vetens.-Akad. Förh. Stockholm, 1861, vol. 17 (for 1860), p. 450; Ann. Phys. Chem. (Poggendorff), 1861, vol. 114, p. 625. W. Florence (Neues Jahrb. Min., 1898, vol. ii, p. 126), who also prepared crystals of zirconia in borax beads, suggested that these might be monoclinic.

investigation. His measurements were made on microscopically small crystals showing only the forms {110}, {111}, and (201). The only line on the photographs that does not also appear on the photograph of natural zirconia is a weak line between the (11$\bar{1}$) and (111) lines corresponding to a spacing of 2·876 Å.U. This may be due to an impurity or it may indicate a larger cell than that taken as unit for baddeleyite. However, no other such indications were found, so that to a first approximation the structures of baddeleyite and of artificially prepared zirconia may be considered as identical.

It will be noticed both from the spectrometer and powder observations that in the case of planes such as (100), (011), (110), (021), &c., from which first-order reflections were found, those reflections were very weak compared with the second orders (200), (022), (220), (420), &c. Also the reflections from general planes with 'all odd' indices, (11$\bar{1}$), (113), (311), &c., are considerably stronger than those from planes with 'mixed' indices. This indicates a nearly face-centred arrangement of the Zr^{++++} ions, which are the chief scattering centres, their maximum scattering power being 36 as compared with 10 for the O^{--} ions. The comparatively large intensity of the (400) indicates that in the [100] direction, at any rate, the O-ions interleave the Zr. J. A. Wasastjerna[1] pointed out that the negative O^{--} ion would be expected to have a much larger radius than the neutral O atom, and calculated from ionic refractions that the 'ionic radius' of O^{--} should be about 1·32 Å.U. W.L. Bragg also found that in a number of substances the distance apart of the O-ion centres is approximately twice this value, and he and G. B. Brown have used this fact in the elucidation of the structure of chrysoberyl.[2] More recently L. Vegard[3] has given a further verification in the cases of anatase, cassiterite, rutile, zircon, and the scheelite group of crystals. The cubic crystals of ThO_2, UO_2, and CeO_2, whose structures most probably conform to the fluorite arrangement, have cube edges $a = 5{\cdot}61$, 5·47, and 5·41 Å.U. respectively.[4] In these cases, therefore, the distances apart of the O centres are $2{\cdot}80_5$, $2{\cdot}73_5$, $2{\cdot}70_5$ Å.U. respectively, and each heavy metallic ion may be visualized as occupying the small space between eight large O-ions arranged cubically about it. It is significant that

[1] J. A. Wasastjerna, Comm. Phys.-Math. Soc. Sci. Fennicae, 1923, vol. 1, no. 38, p. 20.

[2] W. L. Bragg and G. B. Brown, Proc. Roy. Soc. London, Ser. A, 1926, vol. 110, p. 34.

[3] L. Vegard, Phil. Mag., 1926, ser. 7, vol. 1, p. 1151.

[4] V. M. Goldschmidt and L. Thomassen, Vidensk. Skrifter, I. Mat.-naturvid. Kl., Kristiania, 1923, no. 2, p. 5. [Min. Abstr., vol. 2, p. 206.]

in the case of monoclinic zirconia the three axial lengths, taking $\rho = 5{\cdot}73$, are 5·16, 5·21, and 5·32 Å.U. respectively, that is, each about twice the diameter of the O-ion. This fact, together with that of the face-centred arrangement of the Zr-ions, certainly indicates that the whole structure is similar to a distorted fluorite arrangement. The co-ordinates of the Zr-ions would be:

$$(xyz)\,(\tfrac{1}{2}-x, \tfrac{1}{2}+y, \bar{z})\,(x, \tfrac{1}{2}-y, \tfrac{1}{2}+z)\,(\tfrac{1}{2}-x, \bar{y}, \tfrac{1}{2}-z),$$

where x, y, z are all small. Similarly, but with different small values of the parameters, the O co-ordinates would be:

$$(\tfrac{3}{4}+l, \tfrac{3}{4}+m, \tfrac{1}{4}+n)\,(\tfrac{3}{4}-l, \tfrac{1}{4}+m, \tfrac{3}{4}-n)\,(\tfrac{3}{4}+l, \tfrac{3}{4}-m, \tfrac{3}{4}+n)\,(\tfrac{3}{4}-l, \tfrac{1}{4}-m, \tfrac{1}{4}-n)$$
$$(\tfrac{1}{4}+u, \tfrac{3}{4}+v, \tfrac{1}{4}+w)(\tfrac{1}{4}-u, \tfrac{1}{4}+v, \tfrac{3}{4}-w)(\tfrac{1}{4}+u, \tfrac{3}{4}-v, \tfrac{3}{4}+w)(\tfrac{1}{4}-u, \tfrac{1}{4}-v, \tfrac{1}{4}-w).$$

The observed data are too few to allow of any exact determination of these small parameters.

A recent note by W. P. Davey[1] states that powder photographs of different samples of zirconia showed the existence of at least two crystalline forms. In the case of the first 'the strong lines of the pattern taken alone' showed a face-centred cubic lattice, $a = 5{\cdot}098$ Å.U., leading to a probable fluorite arrangement of ions. The second type of pattern indicated a triangular close-packed lattice, $a = 3{\cdot}598$ Å.U., $c/a = 1{\cdot}633$, the structure being closely related to that of the face-centred cube. The second crystalline form is not indicated at all by the results given in the present paper, but the first form (the 'face-centred cubic lattice') is probably the same as the approximately face-centred monoclinic lattice here described, since there were apparently some weaker lines on the photograph which did not agree with a cubic lattice.

This investigation was carried out at the Davy-Faraday Laboratory of the Royal Institution, to the managers of which I am indebted for financial aid. My hearty thanks are due to Sir Wm. Bragg for his unfailing encouragement and to the officials of the British Museum for the loan of crystals and for their ready assistance on many occasions.

[1] W. P. Davey, Bull. Amer. Physical Soc., 1926, vol. 1, no. 9, p. 25.

The crystalline structure of zircon.

By W. Binks, B.Sc. (Manchester).

[Read November 2, 1926; communicated by Professor W. L. Bragg, F.R.S.]

I. *Introduction.*—In a paper recently published by Prof. Vegard[1] is contained an analysis of the structure of the zircon group of crystals, which belong to the tetragonal holohedral class, the axial ratio being approximately $a : c = 1 : 0{\cdot}656$.

As the present work was completed when the above paper appeared, it is interesting to find that the principal deductions concerning the structure of zircon, $ZrSiO_4$, are confirmatory. The parametral values are, however, slightly different. This difference, though small in itself, is found to introduce larger discrepancies between the observed and calculated intensities of reflection.

According to Groth,[2] zircon belongs to the ditetragonal-bipyramidal class. The axial ratio, determined by Kupffer,[3] is $a : c = 1 : 0{\cdot}640373$.

II. *The space-group of zircon.*—A natural specimen from the Urals was employed for observations with the ionization spectrometer. This crystal, of yellowish-brown tint and measuring $15 \times 12 \times 8$ mm., was found by hydrostatic weighing to possess a density of 4·63. Natural faces (111), (110), (100), and (221) were well developed; (001) was absent. Smaller crystals of pyramidal habit, of which the locality was not known, were used for investigation by the Debye-Scherrer method. These were of a dark-brown colour and all approximately of the same size ($4 \times 2 \times 2$ mm.). The density, determined hydrostatically, was 4·67.

A determination of the dimensions of the unit cell was made with the spectrometer, using molybdenum K_α-radiation. This gave:—

$$a = 9{\cdot}30 \text{ Å}, \; c = 5{\cdot}93 \text{ Å}, \; c/a = 0{\cdot}638.$$

Vegard treats the structure as a face-centred one. In order that the comparison between the two sets of results may be facilitated, the crystal is also considered here to be face-centred.

[1] L. Vegard, Phil. Mag., 1926, ser. 7, vol. 1, p. 1151.

[2] P. Groth, Chemische Krystallographie, 1906, vol. 1, p. 92.

[3] A. T. Kupffer, Preisschrift über genaue Messung der Winkel an Krystallen. Berlin, 1825, p. 66.

There are eight molecules $ZrSiO_4$ in the unit cell, the calculated density being 4·68, while the value given by Groth is 4·70.[1]

Inspection of a Debye powder photograph, supplemented by data from spectrometer surveys, gave results which may be summarized thus:

(hhl) is halved if $(h+l)$ is odd.

(hkl) is halved if $(h+k)$, or $(k+l)$, or $(h+l)$ is odd.

($hk0$) is halved if $(h+k)$ is even; quartered if odd.

($0kl$) is halved if $(k+l)$ is even; quartered if odd.

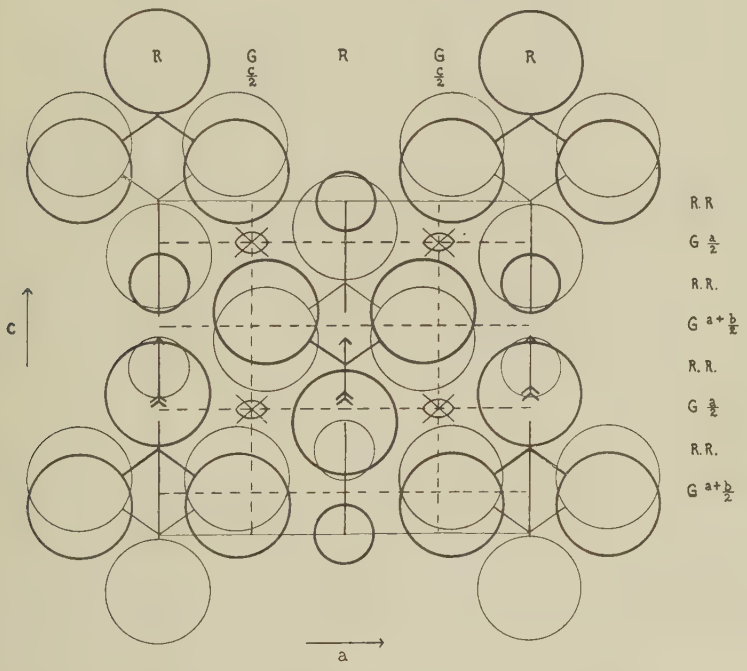

Fig. 1. Structure of zircon, showing the positions of the atoms in the reflection plane (110). The large circles represent oxygen atoms, the small ones zirconiums. Silicon atoms (not shown) lie at the centres of tetrahedral groups of oxygens. Atoms represented by thin lines lie in the reflection plane immediately below the plane containing atoms shown by thick lines.

Assuming that the crystal is holohedral, the space-group is D^{19}_{4h}. The tables of symmetry elements given by Niggli and Wyckoff refer to

[1] Although zircons range from 4·0 to 4·7 in density (Min. Mag., 1904, vol. 14, p. 48).

the body-centred lattice. These can be transformed, in order to be applicable to the face-centred lattice, by rotating the body-centred lattice through an angle $\pi/4$ about the c-axis.

There are two sets of pure reflection planes $(110)_{\frac{1}{4}}$ $(110)_{\frac{3}{4}}$ and $(1\bar{1}0)_{\frac{1}{4}}$

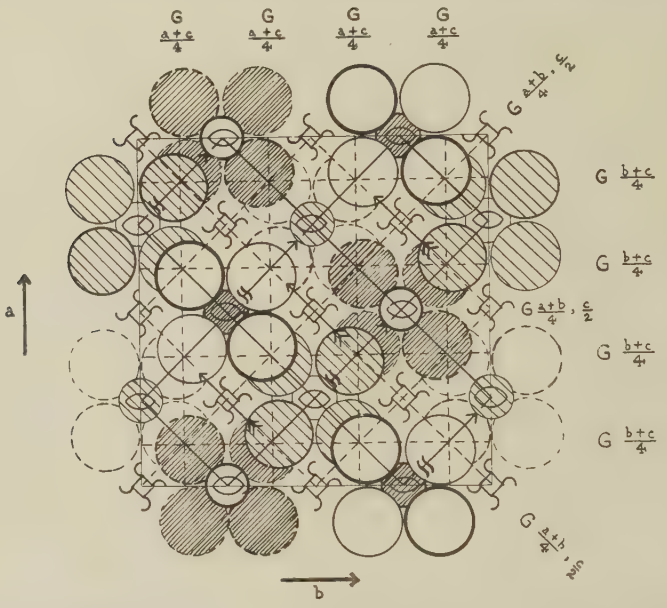

Fig. 2. Structure of zircon. The atoms in the (001) planes are represented in increasing values of c in the following manner: (a) Continuous circles, unshaded. (b) Continuous circles, shaded lightly from left to right downwards. (c) Dotted circles, shaded from right to left downwards. (d) Dotted circles, unshaded. In each tetrahedron, the pair of oxygen atoms thickly outlined lies above the pair thinly outlined. The large circles represent oxygen atoms and the small circles zirconium atoms, the silicons not being shown.

$(1\bar{1}0)_{\frac{3}{4}}$, and two sets of rotation reflection planes $(001)_0$ $(001)_{\frac{1}{2}}$, $(001)_{\frac{1}{4}}$ $(001)_{\frac{3}{4}}$. Glide-planes have the following positions:

$(001)_{\frac{1}{8}}$ $(001)_{\frac{5}{8}}$ $(001)_{\frac{3}{8}}$ $(001)_{\frac{7}{8}}$ —Translation $\frac{a}{4}, \frac{b}{4}$

$(110)_0$ $(1\bar{1}0)_0$ $(110)_{\frac{1}{2}}$ $(1\bar{1}0)_{\frac{1}{2}}$ —Translation $\frac{a+b}{4}, \frac{c}{2}$

$(100)_{\frac{1}{8}}$ $(100)_{\frac{5}{8}}$ $(100)_{\frac{3}{8}}$ $(100)_{\frac{7}{8}}$ —Translation $\frac{a}{4}, \frac{c}{4}$

$(010)_{\frac{1}{8}}$ $(010)_{\frac{5}{8}}$ $(010)_{\frac{3}{8}}$ $(010)_{\frac{7}{8}}$ —Translation $\frac{b}{4}, \frac{c}{4}$

III. *The arrangement of the atoms.*—Symmetry considerations show that, in order to limit the number of atoms to eight in the unit cell, the silicon atoms, and also the zirconium atoms, must lie on the axes of intersection of the two sets of reflection planes,

$$(110)_{\frac{1}{4}}, (1\bar{1}0)_{\frac{1}{4}}; (110)_{\frac{3}{4}}, (1\bar{1}0)_{\frac{3}{4}}.$$

Disregarding for the moment the positions of these atoms along the

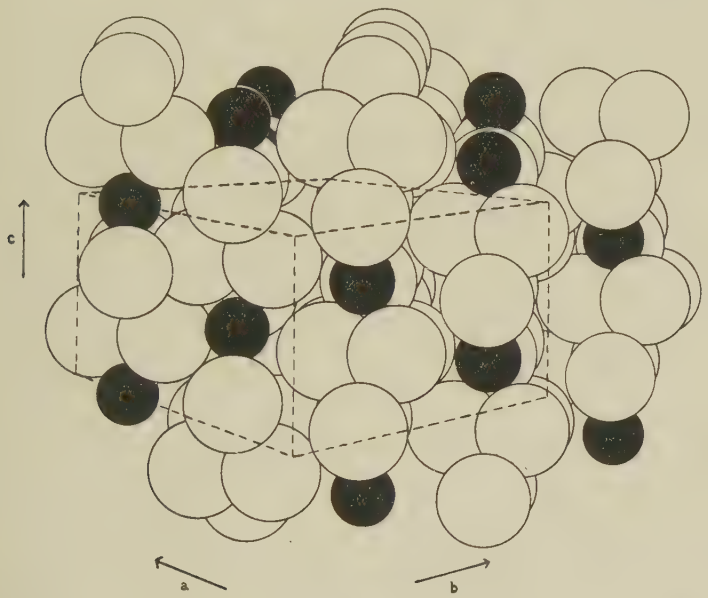

FIG. 3. The zircon structure shown spacially. The black spheres represent zirconium atoms, and the white spheres oxygen atoms grouped in tetrahedra. The silicon atoms lie at the centres of the tetrahedra, and are hidden.

vertical axes, it can be seen that the spacings (100) and (010) are quartered. To effect quartering of the other pinakoidal face, as required by symmetry considerations, the typical silicon atom on the digonal axis $[001]_{0\frac{1}{4}}$ must be placed at one of the four positions on the axis, viz. 0, $\frac{c}{4}$, $\frac{c}{2}$, or $\frac{3c}{4}$. The corresponding zirconium atom, lying on the same vertical axis, is placed at a distance $c/2$ from the silicon atom. That is to say, the silicons and zirconiums would form two interpenetrating face-centred lattices. The construction point may have any of the above values, for the positions of

the derived atoms are identical in the four cases, if viewed from four different construction points, surrounding a tetragonal axis.

Several arrangements of the thirty-two oxygen atoms must be considered:

(*a*) If an atom be placed in a general position (x, y, z) not at a symmetry centre and not on a reflection plane, symmetry operations would give sixty-four atoms to the unit. Consequently, this assemblage must be precluded.

(*b*) The oxygen atoms could be placed at the thirty-two symmetry centres. The amplitude of the reflected wave due to these atoms and to the Si- and Zr-atoms is:—

$$8\cos(h+k+l)\frac{\pi}{4}\cdot\left[\mathrm{Si}+(-1)^l\,.\,\mathrm{Zr}+4\,.\,\mathrm{O}\,.\cos h\frac{\pi}{4}\cdot\cos k\frac{\pi}{4}\cdot\cos l\frac{\pi}{4}\right]$$

$$+8\sin(h+k+l)\frac{\pi}{4}\cdot\left[4\,.\,\mathrm{O}\,.\sin h\frac{\pi}{4}\cdot\sin k\frac{\pi}{4}\cdot\sin l\frac{\pi}{4}\right]\cdot$$

However, calculated and observed intensities are in conflict. For example, the calculated intensity of the reflection (511) is approximately twice that of the reflection (113). In the case of the observed intensity, the reverse holds.

(*c*) The oxygen atoms may lie on the reflection planes, but not at symmetry centres. Several sub-groupings are possible.

(1) Four oxygen atoms may be placed symmetrically round each Si-atom in a plane perpendicular to the digonal axis which passes through the Si-atom. Two arrangements would satisfy symmetry conditions. The atoms could lie either on the planes (110) and ($1\bar{1}0$), or on the planes (100) and (010).

In both cases the distance between two oxygen atoms belonging to adjacent groups is so small that the atoms would penetrate considerably into each other.

The structure amplitude of the wave from atoms situated on the (110) and ($1\bar{1}0$) planes is given by

$$8\cos(h+k+l)\frac{\pi}{4}\cdot\left[\mathrm{Si}+(-1)^l\,.\,\mathrm{Zr}+4\,.\,\mathrm{O}\,.\cos h\theta_1\,.\cos k\theta_1\right]$$

where θ_1 determines the distance Si–O along the line of intersection of the planes (001) and (110).

For the (222) reflection, the structure amplitude is zero. This is

[1] The parameters are expressed as angular differences of phase, the dimensions of the axes representing 360° in their respective directions.

again opposed to observation, for the (222) reflection is 36·3 per cent. of that of NaCl (400 reflection).

(2) Two O-atoms could be associated with a Si-atom and two with a Zr-atom, the O-atoms being situated in the same c-plane as the atom to which they are attached, and on reflection planes at equal distances on each side of the Si- or Zr-atom in consideration. It is justifiable to assume that the distances Si–O and Zr–O are different.

Two arrangements might be considered. If, on the one hand, the O-atoms are distributed so as to lie wholly in the planes (110) or in the perpendicular set, the crystal will not be tetragonal. Moreover, between a Si-atom and a neighbouring Zr-atom would be fixed two oxygen atoms. The distance Si–Zr deduced from cell dimensions is 3·30 Å. It is impossible to pack two O-atoms side by side between the silicon and the zirconium atoms, and we must reject this distribution. On the other hand, the oxygens belonging to the Si-atoms might be situated on the (110) reflection planes, those related to the Zr-atoms being placed on the perpendicular set of planes $(1\bar{1}0)$. The oxygen atoms themselves would then satisfy symmetry requirements, but if considered in conjunction with the Si-atom or the Zr-atom the arrangement would not be tetragonal. With such an arrangement, it is found that the (222) reflection has no finite value, which is contrary to observed facts.

This spectrum would have a finite value if the oxygen atoms were not in the same horizontal planes as the Si- and Zr-atoms. If we displace the two atoms belonging to a silicon, symmetry demands that we move the other set of O-atoms attached to the Zr-atom on the same axis vertically so that the two sets of oxygens lie at equal distances, say θ_2, on each side of the Si-atom, where θ_2 is the c-co-ordinate of the atoms lying in the planes (110) and $(1\bar{1}0)$. The four atoms would have to be equidistant from the digonal axis passing through the Si-atom, and a single parameter θ_1 fixes the positions of the O-atoms in their respective c-planes, θ_1 being the distance along the lines of intersection of the plane (001) with the planes (110) and $(1\bar{1}0)$.

Briefly, each Si-atom is surrounded by four O-atoms placed at the corners of a tetrahedron, the centre of which is occupied by the silicon. The evaluation of the two parameters θ_1 and θ_2 suffices to fix the positions of the O-atoms in the structure. In what follows it will be assumed that this tetrahedron is approximately regular, so that the parameter θ_2 is automatically fixed when θ_1 is evaluated. Examination of other silicates has indicated the probability of a regular SiO_4 group of this kind, though it cannot be regarded as definitely established. The

amplitude of the reflected wave due to all the atoms in the unit is given by

$$8\cos(h+k+l)\frac{\pi}{4}\cdot[\mathrm{Si}+(-1)^l\,.\,\mathrm{Zr}+4\mathrm{O}\,.\cos h\theta_1\,.\cos k\theta_1\,.\cos l\theta_2]$$

$$+8\sin(h+k+l)\frac{\pi}{4}\cdot[4\mathrm{O}\,.\sin h\theta_1\,.\sin k\theta_1\,.\sin l\theta_2]. \quad . \quad . \quad (1)$$

Since the factor 8 occurs in all reflections it may be omitted.

IV. *Evaluation of the Parameters.*—An investigation of the absolute values of a few intensities showed that zircon behaved like a mosaic crystal and therefore the intensity was assumed to be proportional to the square of the structure amplitude. The formula used for the integrated reflection ρ was

$$\rho=\frac{N^2\lambda^3}{4\mu}\cdot\frac{e^4}{m^2c^4}\cdot\frac{1+\cos^2 2\theta}{\sin 2\theta}\cdot S^2(\Sigma F)^2\,.\,e^{-B\sin^2\theta}, \quad . \quad (2)$$

where μ = linear absorption coefficient.

S = structure amplitude.

ΣF = sum of the F factors for the atoms in one molecule, when the atoms are all in phase.

In order to correct for extinction, ρ is assumed to be proportional to $\frac{S^2}{\mu_0+\epsilon}$, where ϵ is the extinction factor, and μ_0 is the ordinary coefficient of linear absorption. The extinction factor is dependent upon the intensity of reflexion ρ, and can be written [1] $\epsilon=a\rho$.

The value of μ_0 for zircon, calculated from Wingårdh's mass absorption coefficients [2] for Mo-radiation is 52·7. In Table I are given the F-values adopted in this paper.

Table I.

Sin θ.	Zr^{+4}.	Si^{+4}.	O^{-2}.
0·00	36·0	10·0	10·0
0·05	35·3	9·9	9·4
0·10	33·7	9·7	6·8
0·15	31·3	9·5	4·6
0·20	28·9	9·1	3·5
0·25	26·5	8·5	2·6
0·30	24·6	7·9	1·9
0·35	23·1	7·3	1·3
0·40	22·1	6·5	0·8
0·45	21·2	5·9	0·4
0·50	20·1	5·1	0·2
0·55	18·8	4·5	0·1
0·60	17·4	3·9	—
0·65	15·8	3·3	—
0·70	14·0	2·9	—

[1] W. L. Bragg, Phil. Mag., 1925, ser. 6, vol. 50, p. 306.
[2] K. A. Wingårdh, Zeits. Physik, 1922, vol. 8, p. 375.

The F-curves for silicon and zirconium are those obtained from Hartree.[1] The oxygen-scattering power curve, however, was rejected because of the increasing values beyond a certain value of the glancing angle. James and Wood [2] found that this curve did not fall away sufficiently rapidly. The same observation was made by Dr. A. Claassen in a determination of F-curves from the magnetite structure. As this work has not yet been published, the author is much indebted to Dr. Claassen for the use of the F-values for oxygen. In a later part of the present paper (Table III), intensities are calculated for lines of the powder spectrum, which was obtained by means of copper K_α-radiation. To obtain the corresponding F-curves, the values in Table I can be used if the glancing angle is multiplied by a factor 2·17, which is the ratio of the wave-length of Cu-K_α-radiation to that of Mo-K_α-radiation.

A theoretical normal reflection curve for various values of $\sin\theta$ was obtained from the formula

$$\rho_n = \frac{N^2\lambda^3}{4\mu_0} \cdot \frac{e^4}{m^2c^4} \cdot \frac{1+\cos^2 2\theta}{\sin 2\theta} \cdot (\Sigma F)^2. \quad . \quad . \quad (3)$$

By comparing equations (2) and (3) we see that, neglecting the temperature factor throughout,

$$\frac{\mu\rho}{S^2} = \mu_0\rho_n, \quad \text{or} \quad \rho_n = \frac{\rho}{S^2} \cdot \frac{\mu_0 + \alpha\rho}{\mu_0}. \quad . \quad . \quad (4)$$

Thus the calculated values of ρ_n obtained from equation (3) should be comparable with the observed values of ρ_n obtained from equation (4). These appear in Table II.

The parametral values chosen are $\theta_1 = 38°$ and $\theta_2 = 60°$, as compared with Vegard's value [3] $\theta_1 = 34°$, and $\theta_2 = 70°$. In consequence, the structure factors are different in the two cases. For the former parametral values, α is estimated to be $4{\cdot}41 \times 10^5$, whereas for the latter set α is $5{\cdot}27 \times 10^5$.

[1] D. R. Hartree, Phil. Mag., 1925, ser. 6, vol. 50, p. 289.

[2] R. W. James and W. A. Wood, Proc. Roy. Soc. London, Ser. A, 1925, vol. 109, p. 588.

[3] L. Vegard (loc. cit.). The parameters α and γ used in Vegard's paper represent the displacements of O-atoms from Zr-atoms, and not, as in the present paper, displacements from Si-atoms. Consequently

$$\theta_1 = \frac{\pi}{2} - \alpha, \text{ and } \theta_2 = \frac{\pi}{2} - \gamma.$$

Table II.

(hkl).	$\sin\theta$.	$\rho \times 10^6$ observed.	With parametral values $\theta_1 = 38°$, $\theta_2 = 60°$. $\frac{\mu_0 + a\rho}{\mu_0} \cdot \rho$.	S^2.	$\frac{\mu_0 + a\rho}{\mu_0} \cdot \frac{\rho}{S^2}$.	$\rho_n \times 10^6$.	With Vegard's values $\theta_1 = 34°$, $\theta_2 = 70°$. $\frac{\mu_0 + a\rho}{\mu_0} \cdot \rho$.	S^2.	$\frac{\mu_0 + a\rho}{\mu_0} \cdot \frac{\rho}{S^2}$.
(111)	0·0805	80·0	133·6	0·0566	2360	2360	144·0	0·0610	2360
(222)	0·1610	35·1	45·4	0·0605	750	680	47·5	0·0272	1746
(333)	0·2415	20·8	24·4	0·0930	262	274	25·2	0·130	194
(444)	0·3220	48·0	67·3	0·581	116	130	71·7	0·719	99·7
(555)	0·4025	5·2	5·4	0·961	56·5	66·7	5·5	0·0773	71·2
(666)	0·4830	?	?	0	?	36·5	?	0·000029	?

The discrepancy between the calculated and observed values of ρ_n for the (222) reflection appearing in columns 7 and 10 is rather large. The agreement between values in columns 6 and 7 is indeed much better than between those in columns 7 and 10.

A more complete, but less accurate, analysis was then effected by means of the powder photograph. Table III has been drawn up on the lines of that in Vegard's paper, and will enable an easy comparison to be made.

The cell dimensions had been previously determined by the spectrometer method. The values were found to be applicable to photographic measurements, as will be seen on glancing at columns 5 and 6. In the latter column appear the calculated spacings determined from the relation

$$\frac{\lambda}{2\sin\theta} = \frac{d}{n} = \frac{a}{\sqrt{h^2 + k^2 + \left(\frac{a}{c}\right)^2 l^2}}.$$

The theoretical intensity of reflection is given by the relation

$$I = N.(\Sigma F)^2.\frac{1+\cos^2 2\theta}{\sin 2\theta}.e^{-B\sin^2\theta},$$

where N = number of planes corresponding to the form $\{h\,k\,l\}$.

ΣF = sum of the F-factors for the atoms in a molecule.

$\frac{1}{\sin 2\theta}$ = correction factor for the increase in diffusion of the reflected beam in passing from the direction of the incident beam to the perpendicular direction.

The structure amplitude for any plane $(h\,k\,l)$ is given by equation (1), in which is substituted the values $\theta_1 = 38°$, $\theta_2 = 60°$. The temperature factor $e^{-B\sin^2\theta}$ is neglected throughout in calculating the intensities of

reflection. The method of evaluating observed intensities is, though not very accurate, yet sufficiently satisfactory to allow comparisons to be made between neighbouring lines on the film, and it furnishes us with an idea of the intensity distribution throughout the spectrum.

Table III.

No. of line.	S.	$\theta°$.	$\sin\theta$.	$\frac{d}{n}$ (obs.).	$\frac{d}{n}$ (calc.).	(*hkl*).	Calc. Intensity.	Nature of line.[1]	Estimate of Intensity.
1	1·76	10·05	0·1744	4·413	4·410	(111)	79·4	m. +	40
2	2·37	13·53	0·2338	3·291	3·290	(220)	147·5	v.v.s.	120
3	2·98	17·02	0·2927	2·629	2·636	(311)	23·8	w.—	10
4	3·12	17·82	0·3060	2·515	2·503	(202)	125·0	s.	70
5	3·37	19·23	0·3293	2·336	2·325	(400)	21·1	w.	15
6	3·58	20·43	0·3490	2·205	2·205	(222)	12·1	w.—	10
7	3·83	21·85	0·3721	2·068	2·057	(331)	25·3	m.—	25
8	4·16	23·75	0·4026	1·912	1·897	(113)	18·2	w. +	20
9	4·58	26·12	0·4402	1·748	1·744	(511)	10·7	w.—	10
10	4·69	26·75	0·4500	1·710	1·701	(422)	100	v.s.	100
11	4·89	27·93	0·4683	1·644	1·645	(440)	40·1	m. +	40
					1·643	(133)			
12	5·22	29·82	0·4973	1·545	1·540	(351)	8·4	w.—	10
					1·483	(004)	5·4	absent	—
13	5·52	31·52	0·5227	1·472	1·471	(620)	31·9	m.	30
					1·470	(333)			
					1·438	(442)	0	absent	—
14	5·95	33·98	0·5587	1·374	1·374	(602)	27·8	m.	30
15	6·01	34·33	0·5639	1·365	1·354	(224)	21·6	w. +	20
					1·342	(513)	1·9	absent	—
					1·318	(622)	1·2	absent	—
16	6·43	36·72	0·5978	1·287	1·284	(551)	11·6	w.—	10
					1·284	(711)			
17	6·61	37·75	0·6121	1·257	1·252	(404)	21·6	w. +	20
					1·243	(533)	5·5	absent	—
					1·209	(244)	0·3	absent	—
					1·196	(731)	1·0	absent	—
18	7·10	40·55	0·6500	1·184	1·183	(462)	24·7	m.—	25
19	7·24	41·34	0·6604	1·165	1·169	(115)	10·9	w.—	10
					1·163	(800)			
20	7·74	44·20	0·6972	1·104	1·103	(444)	17·6	w. +	20
					1·102	(315)			
21	7·80	44·54	0·7013	1·096	1·097	(660)			
					1·096	(553)	13·9	w.	15
					1·096	(713)			
					1·064	(751)	2·7	absent	—
22	8·20	46·82	0·7292	1·055	1·054	(822)	21·4	m.—	25

v.s. = very strong, s. = strong, m. = medium, w. = weak, v.w. = very weak.

Table III (continued):

No. of line.	S.	$\theta°$.	$\sin\theta$.	$\frac{d}{n}$ (obs.).	$\frac{d}{n}$ (calc.).	(*hkl*).	Calc. Intensity.	Nature of line.[1]	Estimate of Intensity.
23	8·26	47·18	0·7333	1·049	1·045	(624)	22·8	m.—	25
					1·045	(335)			
24	8·34	47·62	0·7387	1·041	1·040	(480)	12·2	w.—	10
					1·040	(733)			
					1·029	(662)	0	absent	—
					1·012	(911)	1·8	absent	—
25	8·82	50·37	0·7700	0·999	0·997	(155)	3·9	v.w.	5
					0·982	(842)	0	absent	—
					0·974	(644)	0	absent	—
26	9·23	52·71	0·7956	0·967	0·969	(206)	14·2	w.—	10
					0·967	(931)			
27	9·46	54·03	0·8092	0·951	0·953	(355)	6·1	v.w.	5
					0·949	(753)			
					0·949	(226)			
					0·926	(771)	2·4	absent	—
28	10·03	57·27	0·8411	0·915	0·916	(804)	29·0	w.+	20
					0·912	(10.2.0)			
					0·912	(913)			
					0·898	(824)	0·2	absent	—
29	10·41	59·44	0·8610	0·894	0·894	(426)	26·6	w.+	20
					0·893	(951)			
30	10·50	59·96	0·8656	0·889	0·888	(10.0.2)	36·4	m.—	25
					0·888	(862)			
31	10·64	60·77	0·8726	0·882	0·882	(664)	16·1	w.—	10
					0·882	(555)			
					0·882	(715)			
					0·879	(933)	3·2	absent	—
					0·872	(10.2.2)	0·3	absent	—
32	11·25	64·24	0·9006	0·855	0·852	(844)	34·9	m.—	25
					0·852	(735)			
					0·849	(773)	2·2	absent	—
					0·848	(446)			
					0·842	(117)	1·0	absent	—
33	11·80	67·39	0·9230	0·834	0·834	(606)	21·7	w.	15
					0·834	(11.1.1)			
34	11·90	67·95	0·9267	0·830	0·829	(10.4.2)	35·5	m.—	25

V. *Atomic distances.*— The distance Si–O is found to be 1·70 Å. Each Zr-atom is surrounded by eight oxygen atoms, four at distances 1·96 Å., and four at distances 2·41 Å., the latter four being situated, two above and two below. The centre distance between the two nearest O-atoms is 2·77 Å.

[1] v.s. = very strong, s. = strong, m. = medium, w. = weak, v.w. = very weak.

Summary.—An examination of the structure of zircon, $ZrSiO_4$, has been made by the ionization spectrometer and by a Debye-Scherrer powder photograph. The lattice upon which the structure is based corresponds to the space-group D_{4h}^{19}, possessing the symmetry of the ditetragonal-bipyramidal class. The unit cell, containing eight molecules $ZrSiO_4$, has the dimensions $a = 9{\cdot}30$, $c = 5{\cdot}93$ Å.

The silicon and zirconium atoms form two interpenetrating face-centred lattices. Eight digonal axes pass vertically through each unit cell and on each axis is situated one silicon and one zirconium lying at a distance $c/2$ apart. Symmetry considerations limit the assembling of oxygen atoms to tetrahedra, each enclosing a silicon atom. All the atoms in the structure are situated on reflection planes.

The structure resembles in some ways that of anhydrite, $CaSO_4$, an account of which appears in another paper.[1] The analogous dispositions of atoms in the planes (110) in zircon and in the planes (001) in anhydrite is most interesting. The distribution of atoms about the c-axis in zircon is similar to that about the a-axis in anhydrite.

In conclusion the author wishes to express his sincere thanks to Professor W. L. Bragg, F.R.S., at whose suggestion the research was attempted, for his keen interest and instructive advice. The author is indebted also to Mr. R. W. James, M.A., for his helpful criticism, and to Mr. J. Thewlis, B.Sc., for his kindness in taking the powder photograph.

Manchester University,
July, 1926.

[1] E. C. S. Dickson and W. Binks, Phil. Mag., 1926, ser. 7, vol. 2, p. 114.

Three South African meteorites: Vaalbult, Witklip, and Queens Mercy.

(With Plate III.)

By G. T. Prior, M.A., D.Sc., F.R.S.
Keeper of the Mineral Department of the British Museum.

[Read November 3, 1925, and June 15, 1926.]

Meteoric Iron of Vaalbult farm, Prieska Division, Cape Province.

A SMALL portion (B.M. 1921, 274) of the Vaalbult meteoric iron, weighing about 184 grams, was kindly placed at the disposal of the writer for examination by the late Dr. L. Peringuey, Director of the South African Museum, Cape Town. According to information received from him, this meteorite is known as the 'Vaalbult' siderite, and was presented to the South African Museum on April 22, 1918, by Mr. S. Grove, Member of the Provincial Council of the Cape for the Prieska Division, who obtained it from Mr. Japie Greeff, the owner of the farm on which it was found, probably early in the same year. The original mass weighed about 26 lb. and was very deeply and broadly pitted. In external appearance it is somewhat similar to the large (1,210 lb.) Ratteldraai iron from the Kenhardt Division, more than 60 miles distant, found in 1909. A cast of the iron sent by Dr. Peringuey shows that it is of very irregular shape. On one side are large (4 to 5 inches long and 2 to 3 inches broad) cavernous depressions of roughly oval outline. Other surfaces are smoother but show two or three deep holes, with circular outlines up to 1 inch across, which may possibly have been originally occupied by troilite nodules.

Etching of a polished surface showed that the iron is a coarse to coarsest octahedrite, the kamacite bands having a breadth of from 2 to 4 mm. Taenite bands bordering the kamacite are very narrow but distinctly visible. The arrangement of the kamacite bands is regular in parts where the breadth is about 2 mm., but irregular in others where

the bands are broader, and the structure generally is interrupted by rounded grains with no definite orientation. Plessite is practically absent. The small specimen under examination was comparatively free from inclusions, only one lenticular patch, 8 mm. long, of schreibersite being observed. Examination of the etched polished face under the microscope by reflected light obtained from a Watson-Conrady illuminator showed that schreibersite marks the boundaries between plates and grains of kamacite to as large an extent as taenite. Schreibersite (rhabdite) is seen also as minute square and rhomb-shaped sections scattered plentifully over the polished surface. The larger and irregular plates of kamacite show well-marked Neumann lines. The structure is coarser than the Ratteldraai iron; it is about as coarse as the Karee Kloof iron,[1] but shows, in accordance with its lower percentage of nickel, less taenite.

Chemical analysis of a portion of the iron apparently free from inclusions and weighing 6·7788 grams, gave the following results:

Fe.	Ni.	Co.	Cu.	P.	S.	Insol.	Total.	Sp. gr.
92·18	6·99	0·68	0·02	0·19	trace	0·02	100·08	7·62

In the analysis, the iron was separated from the nickel by a double precipitation with sodium acetate followed by a double precipitation with ammonia. The insoluble consisted of a little carbonaceous matter, angular chips of quartz nd a little felspar), and a few very minute spherical bodies like chondrules, some opaque milk-white and others black; no isotropic grains or cliftonite were detected. One chip of felspar showed twin-lamellae giving extinctions of about 12°.

The Vaalbult iron is a coarse octahedrite having a percentage of nickel of about 7 and a ratio of iron to nickel of about 13.

Meteoric stone of Witklip, Carolina District, Transvaal.

A small fragment weighing $3\frac{1}{2}$ grams was presented to the Museum collection by the late Dr. L. Peringuey. According to an account of the fall of this stone given in Circular No. 44, January 17, 1919, of the Union Observatory, Cape Town, on the morning of May 26, 1918, at about 9.40 a.m., a large meteor passed over the town of Barberton in the eastern Transvaal. Observers near that town heard a loud explosion and some saw a bright flash near the zenith. An observer near Amsterdam, about 54 miles SW. of Barberton, also saw the flash, but

[1] G. T. Prior, Min. Mag., 1923, vol. 20, pp. 134–137.

heard no report. The meteorite left a 'cloudy trail' in the sky which persisted for about half an hour. On August 10, 1918, four or five fragments of a stony meteorite, weighing together about 22 grams, and stated to have fallen on the farm of Witklip, Carolina District, Transvaal, on May 26, 1918, were received by the Union Observatory, through the editor of 'De Volkstem', Pretoria, and were chemically examined by Dr. J. Moir of the Government Chemical Laboratory.

The fragment (B.M. 1921, 275) sent to the British Museum by Dr. Peringuey shows no crust. This, according to Dr. J. Moir, is 'deep brown-olive in colour and is very thin—not much over $\frac{1}{10}$ mm. on the whole'. The interior of the stone is grey in colour, somewhat friable and shows some well-defined spherical chondrules and clear-cut cavities from which chondrules have broken away. On a cut surface, strings and grains of nickel-iron are fairly plentiful and troilite is present in smaller amount. A micro-section under the microscope shows nickel-iron and troilite, orthorhombic pyroxene polarizing in greys, olivine clear and colourless, and twinned clinobronzite in a tufaceous matrix of small grains of the same minerals. Chondrules are fairly abundant, some of which have clearly marked circular sections, but most are ill defined and pass gradually into the matrix. They are of the usual types, some barred with alternating orthorhombic pyroxene and deep-brown glass with a rim of pyroxene in optical continuity with the bars, and some are of the porphyritic type showing well-defined olivine in a dark base which under a high power is seen to consist mainly of fibrous pyroxene having a high extinction-angle. Felspathic material and maskelynite are present in only small amount; no merrillite was detected.

The Witklip meteoric stone is a grey chondrite and, as it somewhat closely resembles that from Cronstad and contains a fairly high percentage of nickel-iron, it is in all probability a bronzite-chondrite.

Meteoric Stone of Queens Mercy, Matatiele, Griqualand East, Cape Province.

Fragments of the Queens Mercy meteorite were kindly placed at my disposal for examination by Dr. A. W. Rogers, Director of the Geological Survey of South Africa, Mr. E. Warren, Director of the Natal Museum at Pietermaritzburg, and Mr. E. C. Chubb, Curator of the Durban Museum.

Of this meteorite two stones at least and probably more fell at about

8 p.m. on April 30, 1925, after appearance of a bright light and a loud detonation. The largest stone, according to an account by Mr. A. J. R. Atkin, fell 'at 8.15 p.m.' at Queens Mercy about 20 miles from Matatiele, Cape Province. There was a loud noise and a bright light, and the natives fled to the bush and found the meteoric stone next morning near a hut. It was a large stone measuring about $18 \times 12 \times 9$ inches and projecting about one foot above the ground. As the medicine-man said that if used as a talisman good luck would come to the wearers, the stone was broken up and distributed in small pieces as 'muti', and only a few fragments, two, however, weighing over 6 lb. each, appear to have been recovered. The smaller nearly complete stone was obtained from Chief Jeremiah Moshesh and handed over to Mr. Warren by Mr. G. Pyke, Postmaster of Matatiele. According to Mr. Pyke's account it fell 'at 7.55 p.m. and fell from east to west. I saw it and also saw it break up. There was a bright light like a motor head-light. After it burst I heard a noise exactly like thunder which lasted about three seconds (I walked a distance of about 100 yards between the bursting and the noise). It fell about 15 miles from here (Matatiele) and over a radius of about 5 miles, just under, or within five miles of the Drakensberg range.' The time of fall, 7.55 p.m., was given by Mr. Pyke, as he 'happened to be coming out of our public library at the time and had just looked at the clock on passing out of the door'.

Of the specimens of this meteorite now in the British Museum collection, the uncrusted fragments weighing about 50 grams (B.M. 1925, 1038) from Dr. Rogers, and a crusted piece weighing 30 grams (B.M. 1926, 219) from Mr. Chubb, came from the larger stone, a crusted piece weighing 52 grams (B.M. 1926, 180) from the small stone. The fragments from the large stone show curious slickensided surfaces with the iron streaked and flattened out in patches probably along the veins. In thin section under the microscope some displacement along the veins is also seen to have taken place. The small complete stone weighed about 950 grams. As seen in outline in the photographs (Plate III, figs. 1 and 2) it is roughly of lozenge shape. Four fairly smooth faces meet in rounded edges (fig. 1) and show only one or two 'thumb-marks', and four other faces have more uneven surfaces (fig. 2) with rather more 'thumb-marks'. The crust, which is about $\frac{1}{2}$ mm. thick, is rough with small pimples, probably of fused iron, and shows a few slightly raised ridges of fused material, but no definite lines of flow are to be distinguished, though there is a glassy thickening on some of the edges

of the stone and adhering flakes of fused material on the less smooth faces. A smooth cut surface shows the stone to be of grey colour and traversed by numerous thin black veins or cracks. Grains of iron are thickly distributed and one piece of troilite 4 mm. long is to be seen. Only a few chondrules of fairly definite circular outline and surrounded by a ring of iron-grains are visible.

In thin section under the microscope the stone presents no unusual characters, but resembles very closely the Witklip and Cronstad stones. Chondrules are mostly ill defined and fragmental, so that the stone has the appearance of being made up largely of these bodies partly re-absorbed, and even one or two fairly sharply defined crystals of olivine and pyroxene may have been originally included in chondrules. Polysomatic porphyritic olivine chondrules are indeed the most common; in some, the porphyritic olivines are enclosed in brown glass, in others in what appears to be fibrous pyroxene black with inclusions. Chondrules of fibrous pyroxene and the barred type are not common. One or two chondrules consist of grains of fairly uniform size of both olivine and pyroxene with a little interstitial felspar. Only a little interstitial felspar and no maskelynite was seen. Troilite is present in comparatively small amount in quite small grains associated with the much more abundant nickel-iron. The pyroxenes are mostly of bronzite giving straight extinction.

A partial chemical analysis was made, by the methods described in previous papers, on about 11 grams of the material sent by Dr. Rogers. The attracted material weighed 2·7152 grams, and the unattracted 8·3940. The proportion of insoluble to soluble material in the unattracted material, as determined on 3·4994 grams, was 1·8445 : 1·6549 grams. The result of the analysis was as follows:

Fe (+Co) by diff.	Ni.	FeS.[1]	Insol. silicate.	Soluble silicate.	Total.
(14·26)	1·35	5·42	44·18	34·49	100·00

The result of a quantitative analysis of the insoluble silicate (pyroxene) of the unattracted material weighing 0·5172 grams was as follows:

SiO_2.	Al_2O_3.	Cr_2O_3.	FeO.	MnO.	CaO.	MgO.	Na_2O and loss.	Total.
53·98	4·78	0·36	9·28	trace	2·03	25·19	(4·38)	100·00

From these results the ratio Fe : Ni is about $10\frac{1}{2}$, and MgO : FeO about 5. The composition of the stone can therefore be expressed by

[1] From determination of sulphur, S = 1·98 per cent.

the formula $f_{15\cdot5}n_{10\cdot5}m_5t_{5\cdot5}$, f denoting percentage of nickel-iron, n the ratio of iron to nickel in it, m the ratio of magnesia to ferrous oxide in the insoluble silicate, and t the percentage of troilite.

The Queens Mercy meteoric stone is a veined grey bronzite-chondrite of the Cronstad type.

Explanation of Plate III

Photographs of the smaller stone (weighing 950 grams) of the meteoritic fall on April 30, 1925, at Queens Mercy, Matatiele, Griqualand East, Cape Province, South Africa. Figs. 1 and 2 viewed from the two sides.

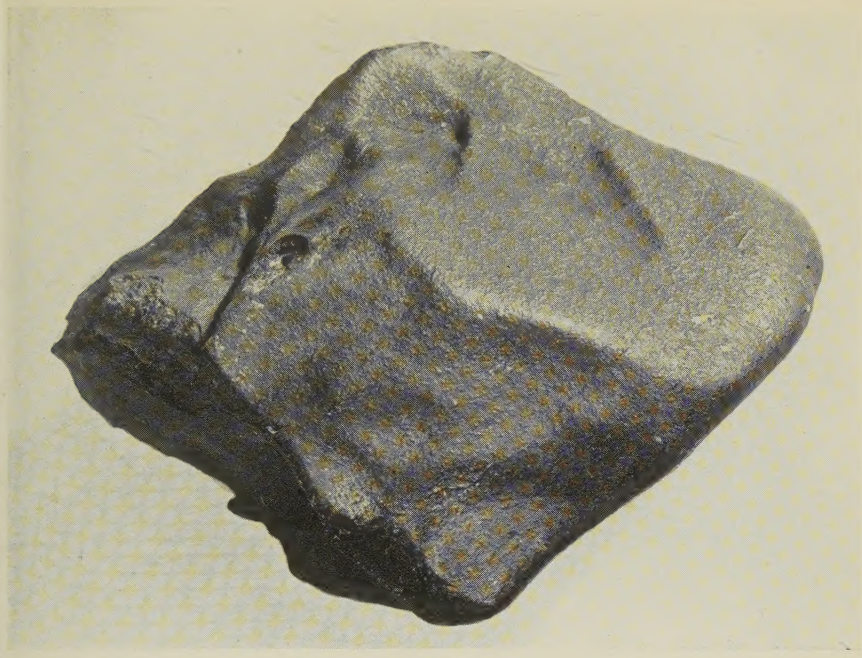

Fig. 1

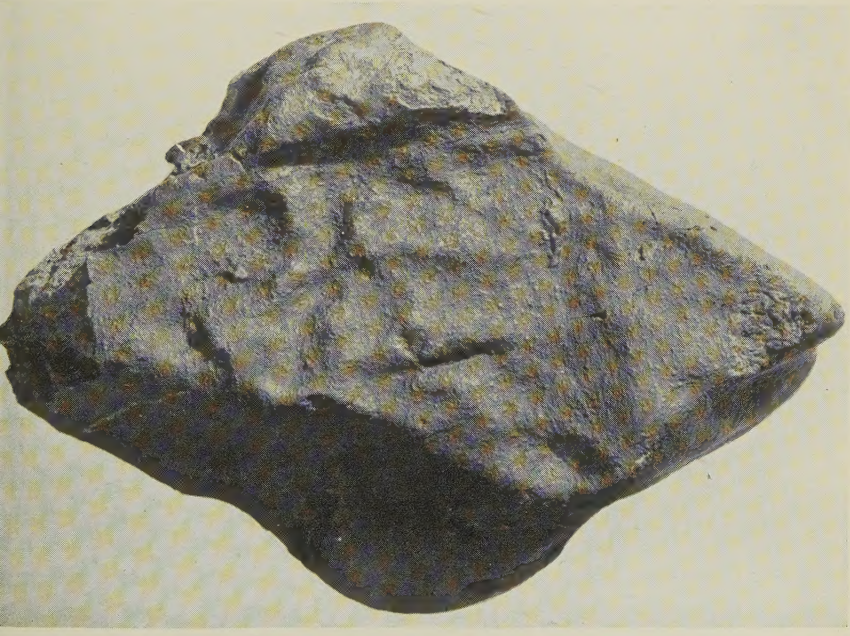

Fig. 2

G. T. Prior: The Queens Mercy (South Africa) Meteorite.

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